



United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station



United States
Department of the
Interior

Bureau of Land
Management

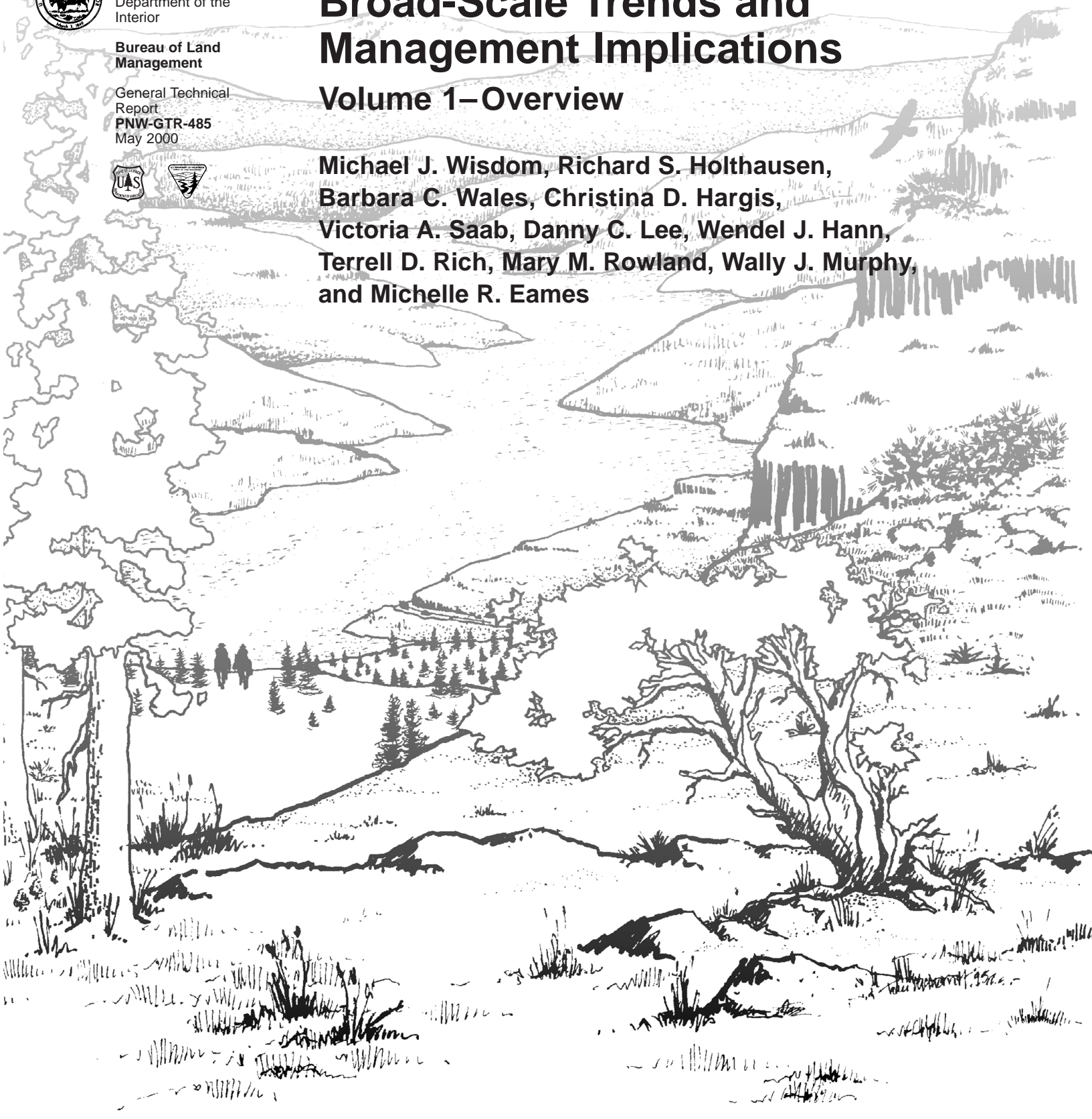
General Technical
Report
PNW-GTR-485
May 2000



Source Habitats for Terrestrial Vertebrates of Focus in the Interior Columbia Basin: Broad-Scale Trends and Management Implications

Volume 1—Overview

Michael J. Wisdom, Richard S. Holthausen,
Barbara C. Wales, Christina D. Hargis,
Victoria A. Saab, Danny C. Lee, Wendel J. Hann,
Terrell D. Rich, Mary M. Rowland, Wally J. Murphy,
and Michelle R. Eames

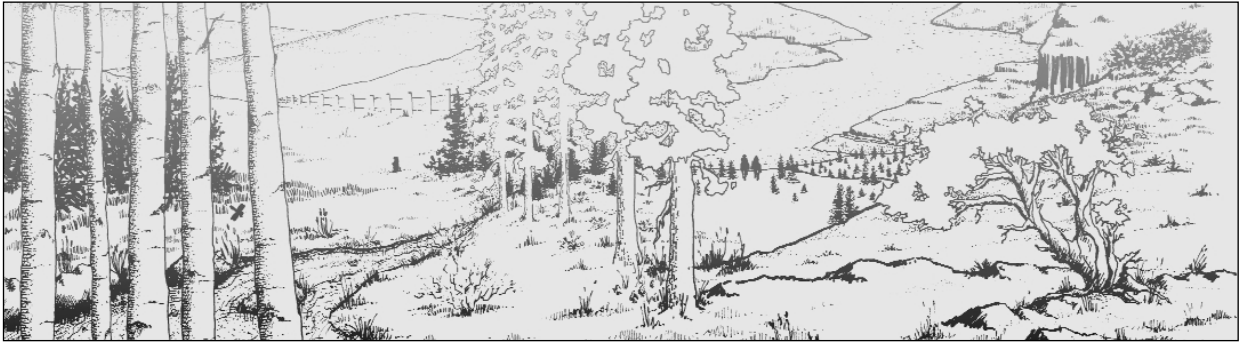


Authors

Michael J. Wisdom is a terrestrial ecologist and **Barbara C. Wales** is a wildlife biologist, USDA Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850; **Richard S. Holthausen** is the national wildlife ecologist and **Christina D. Hargis** is the associate national wildlife ecologist, USDA Forest Service, Rocky Mountain Station, Forestry Sciences Laboratory, 2500 S. Pine Knoll, Flagstaff, AZ 86001; **Danny C. Lee** was a research biologist and **Victoria A. Saab** is a research wildlife biologist, USDA Forest Service, Rocky Mountain Station, Forestry Sciences Laboratory, 316 E. Myrtle St., Boise, ID 83702; **Wendel J. Hann** is the national landscape ecologist, National Interagency Fire Center, Boise, ID 83705; **Terrell D. Rich** is the senior avian ecologist, USDI Bureau of Land Management, 1387 S. Vinnell Way, Boise, ID 83709; **Mary M. Rowland** is a wildlife biologist, USDI Bureau of Land Management, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850; **Wally J. Murphy** was a natural resources staff officer, USDA Forest Service, Umatilla National Forest, 2517 S.W. Hailey, Pendleton, OR 97801; and **Michelle R. Eames** is a wildlife biologist, USDI Fish and Wildlife Service, 11103 E. Montgomery Drive, Suite 2, Spokane, WA 99206.

Contributors

David A. Newhouse, Fred B. Samson, Alan Sands, and Nancy Warren



Source Habitats for Terrestrial Vertebrates of Focus in the Interior Columbia Basin: Broad-Scale Trends and Management Implications

Volume 1—Overview

Michael J. Wisdom, Richard S. Holthausen, Barbara C. Wales,
Christina D. Hargis, Victoria A. Saab, Danny C. Lee, Wendel J. Hann,
Terrell D. Rich, Mary M. Rowland, Wally J. Murphy, and Michelle R. Eames

Interior Columbia Basin Ecosystem Management Project: Scientific Assessment

Thomas M. Quigley, Editor

Volume 1 contains pages 1 through 156.

U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, Oregon
General Technical Report PNW-GTR-485
May 2000

Abstract

Wisdom, Michael J.; Holthausen, Richard S.; Wales, Barbara C.; Hargis, Christina D.; Saab, Victoria A.; Lee, Danny C.; Hann, Wendel J.; Rich, Terrell D.; Rowland, Mary M.; Murphy, Wally J.; Eames, Michelle R. 2000. Source habitats for terrestrial vertebrates of focus in the interior Columbia basin: broad-scale trends and management implications. Volume 1—Overview. Gen. Tech. Rep. PNW-GTR-485. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 3 vol. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).

We defined habitat requirements (source habitats) and assessed trends in these habitats for 91 species of terrestrial vertebrates on 58 million ha (145 million acres) of public and private lands within the interior Columbia basin (hereafter referred to as the basin). We also summarized knowledge about species-road relations for each species and mapped source habitats in relation to road densities for four species of terrestrial carnivores. Our assessment was conducted as part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP), a multiresource, multidisciplinary effort by the USDA Forest Service (FS) and the USDI Bureau of Land Management (BLM) to develop an ecosystem-based strategy for managing FS and BLM lands within the basin. Our assessment was designed to provide technical support for the ICBEMP and was done in five steps. First, we identified species of terrestrial vertebrates for which there was ongoing concern about population or habitat status (species of focus), and for which habitats could be estimated reliably by using a large mapping unit (pixel size) of 100 ha (247 acres) and broad-scale methods of spatial analysis. Second, we evaluated change in source habitats from early European settlement (historical, circa 1850 to 1890) to current (circa 1985 to 1995) conditions for each species and for hierarchically nested groups of species and families of groups at the spatial scales of the watershed (5th hydrologic unit code [HUC]), subbasin (4th HUC), ecological reporting unit, and basin. Third, we summarized the effects of roads and road-associated factors on populations and habitats for each of the 91 species and described the results in relation to broad-scale patterns of road density. Fourth, we mapped classes of the current abundance of source habitats for four species of terrestrial carnivores in relation to classes of road density across the 164 subbasins and used the maps to identify areas having high potential to support persistent populations. And fifth, we used our results, along with results from other studies, to describe broad-scale implications for managing habitats deemed to have undergone long-term decline and for managing species negatively affected by roads or road-associated factors.

Our results indicated that habitats for species, groups, and families associated with old-forest structural stages, with native grasslands, or with native shrublands have undergone strong, widespread decline. Implications of these results for managing old-forest structural stages include consideration of (1) conservation of habitats in subbasins and watersheds where decline in old forests has been strongest; (2) silvicultural manipulations of mid-seral forests to accelerate development of late-seral stages; and (3) long-term silvicultural manipulations and long-term accommodation of fire and other disturbance regimes in all forested structural stages to hasten development and improvement in the amount, quality, and distribution of old-forest stages. Implications of our results for managing rangelands include the potential to (1) conserve native grasslands and shrublands that have not undergone large-scale reduction in composition of native plants; (2) control or eradicate exotic plants on native grasslands and shrublands where invasion potential or spread of exotics is highest; and (3) restore native plant communities by using intensive range practices where potential for restoration is highest.

Our analysis also indicated that >70 percent of the 91 species are affected negatively by one or more factors associated with roads. Moreover, maps of the abundance of source habitats in relation to classes of road density suggested that road-associated factors hypothetically may reduce the potential to support persistent populations of terrestrial carnivores in many subbasins. Management implications of our summarized road effects include the

potential to mitigate a diverse set of negative factors associated with roads. Comprehensive mitigation of road-associated factors would require a substantial reduction in the density of existing roads as well as effective control of road access in relation to management of livestock, timber, recreation, hunting, trapping, mineral development, and other human activities.

A major assumption of our work was that validation research will be conducted by agency scientists and other researchers to corroborate our findings. As a preliminary step in the process of validation, we found high agreement between trends in source habitats and prior trends in habitat outcomes that were estimated as part of the habitat outcome analysis for terrestrial species within the basin. Results of our assessment also were assumed to lead to finer scale evaluations of habitats for some species, groups, or families as part of implementation procedures. Implementation procedures are necessary to relate our findings to local conditions; this would enable managers to effectively apply local conservation and restoration practices to support broad-scale conservation and restoration strategies that may evolve from our findings.

Keywords: Cluster analysis, conservation, forest management, habitat, habitat condition, habitat management, habitat trend, interior Columbia basin, Interior Columbia Basin Ecosystem Management Project, landscape ecology, landscape analysis, population viability, rangeland management, terrestrial vertebrates, spatial analysis, species of focus, sink, sink environment, source, source environment, source habitat, source habitats, restoration, species groups, monitoring, validation research, viability, wildlife, wildlife-habitat relations.

Foreword

This publication consists of three volumes so that our findings—which consist of hundreds of tables, figures, pages of text, and supporting citations—could be presented in a manner most usable to resource managers, biologists, and the public. Volume 1 is designed as an overview of objectives, methods, key results, and management implications. Volumes 2 and 3 contain increasingly detailed results that support and complement results in volume 1. We believe that resource managers may find sufficient detail in the generalized results and implications presented in volume 1, but that management biologists and other users of the results and supporting data will want to refer to all three volumes. Results, management implications, and supporting citations provided in volume 2 are especially important to consider as part of step-down implementation procedures and related management conducted by field units within the interior Columbia basin. By contrast, information in volume 1 may be particularly useful in serving broad-scale planning issues, objectives, and strategies for the interior Columbia basin as a whole. Regardless of application, all three volumes are intended to function together as a comprehensive assessment of habitat trends and a summary of other environmental factors affecting terrestrial vertebrates whose population or habitat status is of ongoing concern to resource managers. Data underlying most tables presented in the three volumes also are available at the web site for the ICBEMP: <http://www.icbemp.gov/spatial/metadata/databases>.

Preface

The Interior Columbia Basin Ecosystem Management Project was initiated by the Forest Service and the Bureau of Land Management to respond to several critical issues including, but not limited to, forest and rangeland health, anadromous fish concerns, terrestrial species viability concerns, and the recent decline in traditional commodity flows. The charter given to the project was to develop a scientifically sound, ecosystem-based strategy for managing the lands of the interior Columbia River basin administered by the Forest Service and the Bureau of Land Management. The Science Integration Team was organized to develop a framework for ecosystem management, an assessment of the socioeconomic and biophysical systems in the basin, and an evaluation of alternative management strategies. This paper is one in a series of papers developed as background material for the framework, assessment, or evaluation of alternatives. It provides more detail than was possible to disclose directly in the primary documents.

The Science Integration Team, although organized functionally, worked hard at integrating the approaches, analyses, and conclusions. It is the collective effort of team members that provides depth and understanding to the work of the project. The Science Integration Team leadership included deputy team leaders Russell Graham and Sylvia Arbelbide; landscape ecology—Wendel Hann, Paul Hessburg, and Mark Jensen; aquatic—Jim Sedell, Kris Lee, Danny Lee, Jack Williams, and Lynn Decker; economic—Richard Haynes, Amy Horne, and Nick Reyna; social science—Jim Burchfield, Steve McCool, Jon Bumstead, and Stewart Allen; terrestrial—Bruce Marcot, Kurt Nelson, John Lehmkuhl, Richard Holthausen, Randy Hickenbottom, Marty Raphael, and Michael Wisdom; spatial analysis—Becky Gravenmier, John Steffenson, and Andy Wilson.

Thomas M. Quigley
Editor



United States
Department of
Agriculture



Forest Service



United States
Department of
the Interior



Bureau of Land
Management



Interior Columbia
Basin Ecosystem
Management Project

Executive Summary

Introduction

Habitat for terrestrial wildlife is declining rapidly worldwide. Declines are due to various human causes; increasing urbanization, conversion of lands to agriculture, and intensive management of forests, rangelands, and other biomes to meet human demands for food, shelter, and leisure are key examples. In the United States, declines in habitat during the past century are largely responsible for the dramatic increase in the number of species listed as candidate, threatened, or endangered under the Endangered Species Act (ESA). This rate of habitat loss has led to an accelerated rate of species listings.

In response to such problems, managers of Federal lands are moving increasingly toward broad-scale, ecosystem-based strategies for conserving and restoring habitats. Examples include the Northwest Forest Plan, the Southern Appalachian Assessment, and the Sierra Nevada Assessment. In this paper, we present results of an ecosystem-based analysis of habitat change and a synthesis of road-associated effects on selected terrestrial vertebrates in support of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). The ICBEMP was established in January 1994 through a charter signed by the Chief of the USDA Forest Service (FS) and the Director of the USDI Bureau of Land Management (BLM). The charter directed that work be undertaken to develop and adopt an ecosystem-based strategy for all lands administered by the FS and BLM within the interior Columbia basin (hereafter referred to as the basin). This area extends over 58 million ha¹ (145 million acres) in Washington, Oregon, Idaho, Montana, and small portions of Wyoming, Nevada, California, and Utah. Fifty-three percent of the basin is public land administered by the FS or BLM.

Our purpose for analysis was to (1) develop an understanding of changes in habitats that have occurred across the basin since early European settlement; (2) assess effects of these changes on source habitats for

species of terrestrial vertebrates for which there is ongoing concern about population or habitat status (species of focus); (3) summarize effects of roads and associated factors on populations and habitats of these species; (4) display broad-scale patterns of road density as a spatially explicit measure of road effects on terrestrial vertebrates, particularly in relation to four species of terrestrial carnivores; and (5) synthesize results from these evaluations into major patterns, implications of which could be addressed by managers in the form of broad-scale strategies and practices.

Objectives and Methods

Within our purpose framework, we had six objectives that formed the basis for our methods:

1. Identify species of terrestrial vertebrates whose habitats might require further assessment and management at broad spatial scales within the basin; these species are referred to as broad-scale species of focus. Broad-scale species of focus are vertebrate species whose population size is known or suspected to be declining in response to habitat decline or to nonhabitat effects of human activities, and whose habitats can be estimated reliably by using a large mapping unit (pixel size) of 100 ha (247 acres) and broad-scale methods of spatial analysis. Because our results were targeted for use in broad-scale, ecosystem-based management, our process of identifying species was designed to include all species for which there might be even moderate concern. Our process was not designed to highlight just those species critically in need of attention. Use of an inclusive rather than an exclusive list of species assures that all associated habitats in need of restoration are addressed. Moreover, use of an inclusive list facilitates a holistic approach to maintaining animal communities rather than single species.
2. Determine species relations with source habitats. Source habitats are those characteristics of macro-vegetation that contribute to stationary or positive population growth for a species in a specified area and time. Source habitats contribute to source environments, which represent the composite of all environmental conditions that results in stationary or positive population growth for a species in a specified area and time. The distinction between

¹ See "Abbreviations" table p. 137, for definitions of abbreviated units of measure.

source habitats and source environments is important for understanding our evaluation and its limitations. For example, source habitats for a bird species during the breeding season would include those characteristics of vegetation that contribute to successful nesting and rearing of young but would not include nonvegetative factors such as the effects of pesticides on thinning of eggshells, which also affect production of young.

3. Conduct a spatial assessment of source habitats for all broad-scale species of focus, including an assessment of change in source habitats from early European to current conditions. Our spatial assessment was based on the composition and structure of vegetation estimated to exist during early European settlement (historical, circa 1850 to 1890) and current (circa 1985 to 1995) conditions, based on prior ICBEMP landscape assessments. Specifically, we wanted to relate historical and current estimates of vegetation characteristics to source habitats deemed to contribute to sustainable populations of the species of focus, and to assess changes in those habitats from historical to current periods.
4. Develop a system to evaluate source habitats for individual species as well as for groups of species. Our system was designed to nest evaluations of individual species hierarchically within evaluations conducted for groups of species and for multiple groups (families of groups). Our system was developed to enable managers to identify broad-scale, robust patterns of habitat change that affect multiple species in a similar manner, and to allow managers to address the needs of all species efficiently, accurately, and holistically with the use of broad-scale strategies and practices. Moreover, our system was designed to enable managers to address the needs of either single- or multi-species, depending on objectives, and to check how well an evaluation of a group of species or a family of groups represents evaluations conducted for each species within the group or family. Finally, our system was designed to evaluate source habitats at multiple spatial scales and across time, thus providing maximum flexibility in the conduct of spatial and temporal analyses.
5. Identify species whose populations or habitats may be negatively affected by roads and associated factors, summarize the effects, display the broad-scale

patterns of road density as an index of these effects, and map areas that contain both abundant source habitats and low road densities for selected species of terrestrial carnivores. Areas containing abundant source habitats may not support persistent populations of some species because of the negative effects of factors associated with roads; that is, source habitats may contribute to positive or stationary population growth, but the road effect may override the habitat effect, thereby resulting in a sink environment. Knowledge about the negative effects of factors associated with roads is therefore an important, complementary component to proper management of vegetation for terrestrial vertebrates.

6. Describe the broad-scale implications for managing terrestrial vertebrates whose source habitats have undergone long-term decline, or for terrestrial vertebrates whose habitats or populations are negatively affected by one or more factors associated with roads. Management implications are broad-scale considerations about the potential to conserve or restore source habitats, or to manage human access and human activities, on FS- and BLM-administered lands in response to habitat decline or to negative effects of human disturbance. Describe these implications from results of our assessment, from the scientific literature, and from results of prior assessments conducted as part of the ICBEMP. Whenever possible, link these implications to specific geographic areas of the basin based on our spatial assessment of source habitats and our mapping of broad-scale patterns of road density.

Source Habitats for Families of Groups

We identified 91 species of birds, mammals, and reptiles (broad-scale species of focus) for analysis, based on criteria that indexed various habitat or population problems regarding the current status of each species. Placement of the 91 species into 40 groups, and the further placement of 37 of the groups into 12 families, by using a combination of cluster analysis and empirical knowledge of the similarities of species in habitat requirements, resulted in distinct differences among families in the number of terrestrial community types and source habitats used. Family 4 had the most restricted number of terrestrial community types and source habitats used by species of any family, with

habitats restricted to early-seral forests. Species in family 1 also were restricted to a small number of terrestrial community types, and in this case, the types were composed of low-elevation, late-seral forests. By contrast, species in family 2 used a higher number and variety of terrestrial community types that encompassed all elevations of late-seral forests. Species in family 3 used an even greater variety of forested conditions; habitats encompassed the highest number and type of source habitats within the highest number of terrestrial community types of any family dependent on forested habitats.

Species dependent strictly on rangelands were placed in families 10, 11 and 12. Species in families 11 and 12 were restricted to a relatively small number of terrestrial community types, with family 11 primarily dependent on sagebrush, and family 12 dependent on grassland and open-canopy sagebrush habitats. Species in family 10 used a broader set of terrestrial communities, consisting of various grassland, shrubland, woodland, and related cover types in comparison to families 11 and 12.

Species in families 5, 6, 7, 8, and 9 were associated with various terrestrial community types, but the set of source habitats for each family was distinctly different from the others. Habitats for species in family 9 were restricted to relatively few source habitats within the upland woodland and upland shrubland types. By contrast, species in family 5 used habitats that encompassed nearly all terrestrial community types. Species in family 6 also used various terrestrial communities, with the types composed of forests, woodlands, and montane shrubs. Terrestrial community types used by family 7 were similar to family 6, with the main difference being the use of sagebrush types instead of montane shrubs. Finally, habitats for family 8 spanned a fairly restrictive but unusual combination of terrestrial community types composed of both early- and late-seral forests, as well as woodland, shrubland, and grassland types.

These differences in terrestrial communities and source habitats among the families resulted in distinctly different habitat trends for each family. In the following section, results are summarized in terms of major habitat trends and key implications for management. Also included is a summary of species-road relations, based on a survey of species-roads literature.

Major Findings and Implications

1. Source habitats for most species declined strongly from historical to current periods across large areas of the basin. Strongest declines were for species dependent on low-elevation, old-forest habitats (family 1), for species dependent on combinations of rangelands or early-seral forests with late-seral forests (family 8), and for species dependent on native grassland and open-canopy sagebrush habitats (family 12). Widespread but less severe declines also occurred for most species dependent on old-forest habitats present in various elevation zones (family 2); for species dependent on early-seral forests (family 4); for species dependent on native herbland, shrubland, and woodland habitats (family 10); and for species dependent on native sagebrush habitats (family 11). Source habitats for all of the above-named families have become increasingly fragmented, simplified in structure, and infringed on or dominated by exotic plants.
2. Primary causes for decline in old-forest habitats (families 1 and 2) are intensive timber harvest and large-scale fire exclusion. Additional causes for decline in low-elevation, old-forest habitats are conversion of land to agriculture and to residential or urban development. Intensive timber harvest and large-scale fire exclusion also are primarily responsible for the large decline in early-seral habitats (family 4).
3. Primary causes for decline in native herbland, woodland, grassland, and sagebrush habitats (families 10, 11, and 12) are excessive livestock grazing, invasion of exotic plants, and conversion of land to agriculture and residential and urban development. Altered fire regimes also are responsible for decline in native grassland and shrubland habitats.
4. Various road-associated factors negatively affect habitats or populations of most of the 91 species of focus. Effects of road-associated factors can be direct, such as habitat loss and fragmentation because of road construction and maintenance. Effects also can be indirect, such as displacement or increased mortality of populations in areas near roads in relation to motorized traffic and associated human activities. Because of the high density of roads present across large areas of the basin,

effects from road-associated factors must be considered additive to that of habitat loss. Moreover, many habitats likely are underused by some species because of the effects of roads and associated factors; this may be especially true for species of carnivorous mammals, particularly gray wolf and grizzly bear.²

5. Implications of our results for managing old-forest structural stages include the potential to conserve old-forest habitats in subbasins and watersheds where decline has been strongest; manipulate mid-seral forests to accelerate development of late-seral stages when such manipulations can be done without further reduction in early- or late-seral forests; and restore fire and other disturbance regimes in all forested structural stages to hasten development and improvement in the amount, quality, and distribution of old-forest stages. Many of the practices designed to restore old-forest habitats also can be designed to restore early-seral habitats. For example, long-term restoration of more natural fire regimes will hasten development of both early- and late-seral structural conditions, and minimize area of mid-seral habitats, which few if any species depend on as source habitat.
6. Implications of our results for managing rangelands include the potential to conserve native grasslands and shrublands that have not undergone large-scale reduction in composition of native plants; control or eradicate exotic plants on native grasslands and shrublands where invasion potential or spread of exotics is highest; and restore native plant communities, by using intensive range practices, where potential for restoration is highest. Restoration includes the potential to manipulate livestock grazing systems and stocking rates where existing or past grazing practices have contributed to the decline of native grasslands and shrublands.
7. Implications of our summary of road-associated effects include the potential to mitigate a diverse set of negative factors associated with roads. Comprehensive mitigation of road-associated factors would require a substantial reduction in the

density of existing roads as well as effective control of road access in relation to management of livestock, timber, recreation, hunting, trapping, mineral development, and other human activities. Efforts to restore habitats without simultaneous efforts to reduce road density and control human disturbances will curtail the effectiveness of habitat restoration, or even contribute to its failure; this is because of the large number of species that are simultaneously affected by decline in habitat as well as by road-associated factors.

8. Implications of all our results, when considered at multiple spatial scales ranging from the basin, ecological reporting unit, subbasin, and watershed, provide spatially explicit opportunities for conservation and restoration of source habitats across various land ownerships and jurisdictions. Moreover, our results provide temporally explicit opportunities for design of long-term efforts to restore source habitats that have undergone strong, widespread decline, with simultaneous design of efforts to conserve these same habitats where they exist currently. Use of our findings to conduct effective spatial and temporal prioritization of restoration and conservation efforts for terrestrial species and habitats represents a major opportunity for resource managers in the interior Columbia basin.

² See table 1 for common and scientific names of the vertebrate broad-scale species of focus, and appendix 3, volume 3, for scientific names of plants and animals not addressed as terrestrial vertebrates of focus.

Contents

Volume 1

1	Introduction
4	Objectives
6	Related Assessments
6	Study Area
7	Methods
7	Identifying Species of Focus
9	Delineating Species Ranges
16	Determining Species Relations With Source Habitats
27	Designing a Hierarchical System of Single- and Multi-Species Assessment
29	Clustering the Species into Groups
29	Assessing Change in Source Habitats From Historical to Current Conditions for Species and Groups
34	Forming Families of Groups to Summarize Results Among Multiple Groups
38	Correlating Change in Source Habitats Between Species Within Groups and Families
39	Summarizing Knowledge About Species-Road Relations
40	Mapping Road Density in Relation to Abundance of Source Habitats for Selected Species
40	Interpreting Results and Describing Management Implications
42	Validating Agreement Between Change in Source Habitats and Expert-Opinion Based Habitat Outcomes
43	Species-Level Results and Discussion
43	Habitat Change by Basin and Ecological Reporting Unit
49	Habitat Change on All Lands Versus Public and Mixed Ownership
51	Management Implications
51	Group-Level Results and Discussion
51	Group Membership and Associated Source Habitats
52	Habitat Change by Basin and Ecological Reporting Unit
56	Habitat Change on All Lands Versus Public and Mixed Ownership
56	Correlation of Habitat Trends Among Species Within Groups
61	Management Implications
62	Family-Level Results and Discussion
62	Habitat Relations Among Families
65	Overview of Family-Level Results
69	Correlation of Habitat Trends Among Species Within Families

70	Family 1—Low-Elevation, Old-Forest Family
75	Family 2—Broad-Elevation, Old-Forest Family
79	Family 3—Forest Mosaic Family
83	Family 4—Early-Seral Montane and Lower Montane Family
85	Family 5—Forest and Range Mosaic Family
89	Family 6—Forest, Woodland, and Montane Shrub Family
93	Family 7—Forest, Woodland, and Sagebrush Family
96	Family 8—Rangeland and Early- and Late-Seral Forest Family
98	Family 9—Woodland Family
100	Family 10—Range Mosaic Family
104	Family 11—Sagebrush Family
109	Family 12—Grassland and Open-Canopy Sagebrush Family
112	Species Negatively Affected by Factors Associated With Roads
112	Species-Road Relations
123	Mapping Road Density in Relation to Abundance of Source Habitats for Terrestrial Carnivores
133	Validating Agreement Between Change in Source Habitats and Expert Opinion-Based Habitat Outcomes
133	Major Findings and Implications
137	Acknowledgments
137	Abbreviations
138	References

Volume 2

157	Introduction
161	Group 1—Pygmy Nuthatch, White-Breasted Nuthatch, and White-Headed Woodpecker
161	Results
161	Interpreting Results
165	Management Implications
166	Group 2—Lewis' Woodpecker (Migrant Population)
166	Results
168	Interpreting Results
171	Management Implications
172	Group 3—Western Gray Squirrel
172	Results
176	Interpreting Results
176	Management Implications

177	Group 4—Blue Grouse (Winter)
177	Results
178	Interpreting Results
178	Management Implications
181	Group 5 - Northern Goshawk (Summer), Flammulated Owl, American Marten, and Fisher
181	Results
184	Interpreting Results
188	Management Implications
190	Group 6—Vaux’s Swift, Williamson’s Sapsucker, Pileated Woodpecker, Hammond’s Flycatcher, Chestnut-Backed Chickadee, Brown Creeper, Winter Wren, Golden-Crowned Kinglet, Varied Thrush, Silver-Haired Bat, and Hoary Bat
190	Results
194	Interpreting Results
197	Management Implications
199	Group 7—Boreal Owl
199	Results
200	Interpreting Results
203	Management Implications
204	Group 8—Great Gray Owl
204	Results
205	Interpreting Results
208	Management Implications
209	Group 9—Black-Backed Woodpecker
209	Results
213	Interpreting Results
214	Management Implications
215	Group 10—Olive-Sided Flycatcher
215	Results
218	Interpreting Results
218	Management Implications
219	Group 11—Three-Toed Woodpecker and White-Winged Crossbill
219	Results
223	Interpreting Results
223	Management Implications
224	Group 12—Woodland Caribou
224	Results
224	Interpreting Results
228	Management Implications

229	Group 13—Northern Flying Squirrel
229	Results
230	Interpreting Results
233	Management Implications
234	Group 14 —Hermit Warbler
234	Results
237	Interpreting Results
237	Management Implications
237	Group 15—Pygmy Shrew and Wolverine
237	Results
241	Interpreting Results
242	Management Implications
242	Group 16—Lynx
242	Results
246	Interpreting Results
247	Management Implications
248	Group 17—Blue Grouse (Summer) and Mountain Quail (Summer)
248	Results
248	Interpreting Results
253	Management Implications
254	Group 18—Lazuli Bunting
254	Results
255	Interpreting Results
258	Management Implications
258	Group 19—Gray Wolf and Grizzly Bear
258	Results
260	Interpreting Results
265	Management Implications
266	Group 20—Mountain Goat
266	Results
268	Interpreting Results
271	Management Implications
272	Group 21—Long-Eared Owl
272	Results
273	Interpreting Results
276	Management Implications

276	Group 22—California Bighorn Sheep and Rocky Mountain Bighorn Sheep
276	Results
278	Interpreting Results
282	Management Implications
283	Group 23—Rufous Hummingbird and Broad-Tailed Hummingbird
283	Results
283	Interpreting Results
287	Management Implications
288	Group 24—Sharptail Snake, California Mountain Kingsnake, and Black-Chinned Hummingbird
288	Results
292	Interpreting Results
293	Management Implications
293	Group 25—Northern Goshawk (Winter)
293	Results
297	Interpreting Results
297	Management Implications
298	Group 26—Yuma Myotis, Long-Eared Myotis, Fringed Myotis, and Long-Legged Myotis
298	Results
300	Interpreting Results
304	Management Implications
305	Group 27—Pine Siskin and Townsend’s Big-Eared Bat
305	Results
307	Interpreting Results
310	Management Implications
311	Group 28—Spotted Bat, Pallid Bat, and Western Small-Footed Myotis
311	Results
313	Interpreting Results
316	Management Implications
317	Group 29—Western Bluebird
317	Results
318	Interpreting Results
321	Management Implications
322	Group 30—Ash-Throated Flycatcher and Bushtit
322	Results
326	Interpreting Results
326	Management Implications

327	Group 31—Ferruginous Hawk, Burrowing Owl, Short-Eared Owl, Vesper Sparrow, Lark Sparrow, Western Meadowlark, and Pronghorn
327	Results
331	Interpreting Results
334	Management Implications
336	Group 32—Preble’s Shrew, Uinta Ground Squirrel, White-Tailed Antelope Squirrel, Wyoming Ground Squirrel, Washington Ground Squirrel, Striped Whipsnake, Longnose Snake, Ground Snake, Mojave Black-Collared Lizard, and Longnose Leopard Lizard
336	Results
343	Interpreting Results
344	Management Implications
347	Group 33—Brewer’s Sparrow, Lark Bunting, Sage Sparrow, Sage Thrasher, Sage Grouse, Pygmy Rabbit, and Sagebrush Vole
347	Results
347	Interpreting Results
354	Management Implications
356	Group 34—Kit Fox and Black-Throated Sparrow
356	Results
356	Interpreting Results
360	Management Implications
361	Group 35—Loggerhead Shrike
361	Results
361	Interpreting Results
366	Management Implications
367	Group 36—Columbian Sharp-Tailed Grouse (Summer)
367	Results
372	Interpreting Results
373	Management Implications
374	Group 37—Grasshopper Sparrow, Clay-Colored Sparrow, and Idaho Ground Squirrel
374	Results
376	Interpreting Results
381	Management Implications
383	Group 38—Black Rosy Finch and Gray-Crowned Rosy Finch
383	Results
383	Interpreting Results
383	Management Implications

387 **Group 39—Lewis' Woodpecker (Resident Population)**

387 Results

388 Interpreting Results

391 Management Implications

392 **Group 40—Brown-Headed Cowbird**

392 Results

392 Interpreting Results

393 Management Implications

396 **Abbreviations**

397 **References**

Volume 3

435 **Introduction**

436 **Appendix 1**—Tables

516 **Appendix 2**—Experts, Professional Affiliation, and Associated Taxonomic Groups of Species
Addressed to Define Habitat Requirements

518 **Appendix 3**—Common and Scientific Names of Species

521 **References**

522 **Glossary**

Introduction

Habitat for terrestrial wildlife is declining rapidly worldwide. Declines are due to several human causes; increasing urbanization, conversion of lands to agriculture, and intensive management of forests, rangelands, and other biomes to meet human demands for food, shelter, and leisure are key examples (Alverson and others 1994, Noss and others 1995, Western and Pearl 1989). In the United States, declines in habitat during the past century are largely responsible for the dramatic increase in the number of species listed as candidate, threatened, or endangered under the Endangered Species Act (ESA) (Easter-Pilcher 1996; Flather and others 1994, 1998) (See "Glossary," vol. 3, for terms used in this paper). This rate of habitat loss has led to an accelerated rate of species listings. For example, based on the apparent exponential rate at which species have been listed under ESA during the past 11 years (Flather and others 1994, 1998), the number of species in the United States that may warrant listing early in the 21st century may double, or perhaps triple, the number already listed.

In response to such projections, managers of Federal lands are moving increasingly toward broad-scale, ecosystem-based strategies for conserving and restoring habitats. Examples include the Northwest Forest Plan (USDA Forest Service and USDI Bureau of Land Management 1994), the Southern Appalachian Assessment (SAMAB 1996), and the Sierra Nevada Assessment (Anonymous 1996). Such ecosystem-based strategies are needed to sustain habitats for all species in a holistic manner by using broad-scale methods intended to prevent further listings under ESA. Such strategies also are designed to comply with additional laws regarding maintenance of viable populations, such as the National Forest Management Act (NFMA).

In this paper, we present results of an ecosystem-based analysis of habitat change and a synthesis of road-associated effects on selected terrestrial vertebrates in support of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). The ICBEMP was established in January 1994 through a charter signed by the Chief of the USDA Forest Service (FS) and the Director of the USDI Bureau of Land Management (BLM) (USDA Forest Service 1996). The charter directed that work be undertaken to develop and adopt an ecosystem-based strategy for managing all lands administered by the FS and BLM within the interior

Columbia basin (hereafter referred to as the basin). This area extends over 58 million ha (145 million acres) in Washington, Oregon, Idaho, Montana, and small portions of Nevada, California, Utah, and Wyoming (fig. 1A). Fifty-three percent of the basin is public land administered by the FS or BLM.

The work of the ICBEMP has resulted in new understanding of both the biological and social systems in the basin (Quigley and others 1996, USDA Forest Service 1996). Of most significance to terrestrial vertebrates are the changes in terrestrial habitats and disturbance processes that have occurred since the time of early European settlement. Chief among these changes are dramatic shifts in fire regimes, reductions in area of native grasslands and shrublands, declines in the early and late stages of forest development, reduction in wetland area, deterioration of riparian habitat conditions, and increases in road density (Hann and others 1997, Quigley and others 1996, USDA Forest Service 1996). These changes have reduced habitat for many species within the basin (Lehmkuhl and others 1997, Noss and others 1995), and populations of several vertebrates have declined (Saab and Rich 1997).

This knowledge of biological and social systems has been used to craft ecosystem-based management strategies, and the basis for those strategies has been reported in scientific publications (for example, Hann and others 1997, Hessburg and others 1999; Lee and others 1997, Lehmkuhl and others 1997), as well as in draft environmental impact statements (DEIS) (USDA Forest Service and USDI Bureau of Land Management 1997a, 1997b). These documents detail how current management of Federal lands not only seems inadequate to maintain sufficient habitat for many terrestrial vertebrates, but how the continuation of such management is projected to result in further deterioration of habitats (Lehmkuhl and others 1997). New strategies that are likely to be more favorable to terrestrial vertebrates are those that provide for active restoration of habitats and ecosystem processes. These new strategies are projected to result in maintenance or improvement of habitat for many species and continued deterioration of habitat for fewer species (Lehmkuhl and others 1997).

Although strategies that include an active restoration component hold promise for reversing the deterioration of habitat conditions within the basin, there are many unknowns concerning implementation of those

A



Figure 1—Assessment boundaries of, and land ownership within, the Interior Columbia Basin Ecosystem Management Project (A), and the 13 ecological reporting units (B).

B



Figure 1—Assessment boundaries of, and land ownership within, the Interior Columbia Basin Ecosystem Management Project (A), and the 13 ecological reporting units (B).

strategies. Restoration practices are well understood for some environments but not adequately studied or understood for other habitats (Hann and others 1997). In addition, spatial priorities for implementation of these practices, from the standpoint of terrestrial vertebrates, have received little attention as part of the ICBEMP thus far. The information needed to establish such priorities is spatially explicit knowledge of change in habitat conditions throughout the basin and of resulting effects on vertebrate species. This information, linked with an understanding of the processes that have caused changes and effects on other components of the ecosystem, would facilitate the development of spatially explicit management strategies that span a full range of ecological and social concerns. That was the motivation for our analysis of habitat change and synthesis of road-associated effects on selected terrestrial vertebrates presented here.

Objectives

The purpose for an analysis was to (1) develop an understanding of changes in habitats that have occurred across the basin since early European settlement; (2) assess effects of these changes on source habitats for species of terrestrial vertebrates for which there is ongoing concern about population or habitat status (species of focus); (3) summarize effects of roads and associated factors on populations and habitats of these species; (4) display broad-scale patterns of road density as a spatially explicit measure of road effects on terrestrial vertebrates, particularly in relation to four species of terrestrial carnivores; and (5) synthesize results from these evaluations into major patterns, implications of which could be addressed by managers in the form of broad-scale strategies and practices. Within this framework, we had six specific objectives:

1. Identify species of terrestrial vertebrates whose habitats might require further assessment and management at broad spatial scales within the basin; these species are referred to as broad-scale species of focus. Broad-scale species of focus are vertebrate species whose population size is known or suspected to be declining in response to habitat decline or to nonhabitat effects of human activities, and whose habitats can be estimated reliably by using a large mapping unit (pixel size) of 100 ha (247 acres) and broad-scale methods of spatial analysis. Because our results were targeted for use

in broad-scale, ecosystem-based management, our process of identifying species was designed to include all species for which there might be even moderate concern. Our process was not designed to highlight just those species critically in need of attention. Use of an inclusive rather than an exclusive list of species assures that all associated habitats in need of restoration are addressed. Moreover, use of an inclusive list facilitates a holistic approach to maintenance of animal communities rather than single species.

2. Determine species relations with source habitats. Source habitats are those characteristics of macrovegetation that contribute to stationary or positive population growth for a species in a specified area and time. Source habitats contribute to source environments (Pulliam 1988, Pulliam and Danielson 1991), which represent the composite of all environmental conditions that results in stationary or positive population growth for a species in a specified area and time. The distinction between source habitats and source environments is important for understanding our evaluation and its limitations. For example, source habitats for a bird species during the breeding season would include those characteristics of vegetation that contribute to successful nesting and rearing of young, but would not include nonvegetative factors, such as the effects of pesticides on thinning of eggshells, which also affect production of young.

Consideration of both vegetative and nonvegetative factors that contribute to population persistence requires an evaluation of source environments, which is beyond the purpose and scope of our evaluation. As part of the process of identifying and evaluating vegetation characteristics that contribute to stationary or positive population growth, however, we defined and identified source habitats as being distinctly different from habitats that are simply associated with species occurrence, which may or may not contribute to viable, long-term population persistence. That is, in contrast to source habitats, those habitats in which species occur can contribute to either source or sink environments (Pulliam and Danielson 1991). Consequently, species occurrence by itself indicates little or nothing about the capability of the associated environment to support long-term persistence of populations (Conroy and Noon 1996, Conroy and others 1995).

Consequently, data based strictly on species occurrence did not meet our objective to identify those characteristics of vegetation that contribute to long-term population persistence, which we defined as source habitats.

3. Conduct a spatial assessment of source habitats for all broad-scale species of focus, including an assessment of change in source habitats from early European to current conditions. Our spatial assessment was based on the composition and structure of vegetation estimated to exist during early European settlement (historical, circa 1850 to 1890) and current (circa 1985 to 1995) conditions, based on work by Hann and others (1997) and methods of Keane and others (1996). Specifically, we wanted to relate historical and current estimates of vegetation characteristics to source habitats deemed to contribute to sustainable populations of the species of focus, and to assess changes in those habitats from historical to current periods.
4. Develop a system to evaluate source habitats for individual species as well as for groups of species. Our system was designed to nest evaluations of individual species hierarchically within evaluations conducted for groups of species and for multiple groups (families of groups). Our system specifically was developed to enable managers to identify broad-scale, robust patterns of habitat change that affect multiple species in a similar manner, and to allow managers to address the needs of all species efficiently, accurately, and holistically with the use of broad-scale strategies and practices. Moreover, our system was designed to enable managers to address the needs of either single or multiple species, depending on objectives, and to allow managers to check how well an evaluation of a group of species or a family of groups represents evaluations conducted for each species within the group or family. Finally, our system was designed to evaluate source habitats at multiple spatial scales and across time, thus providing maximum flexibility in the conduct of spatial and temporal analyses.

Use of hierarchically nested single- and multi-species evaluations, conducted at multiple spatial scales, is considered a requirement for managers who need information at different levels of resolution and complexity. Our use of both single- and multi-species

evaluations was designed to provide maximum flexibility in how managers address different issues of habitat management. Our rationale for using both single- and multi-species evaluations, each nested hierarchically within one another, was that each habitat issue requires a different level of detail and knowledge for effective management.

5. Identify species whose populations or habitats may be negatively affected by roads and associated factors, summarize the effects, display the broad-scale patterns of road density as an index of these effects, and map areas that contain both abundant source habitats and low road densities for selected species of terrestrial carnivores. It is possible that areas containing abundant source habitats may not support persistent populations of some species because of the negative effects of factors associated with roads; that is, source habitats may contribute to positive or stationary population growth, but the road effect may override the habitat effect, thereby resulting in a sink environment. Knowledge about the negative effects of factors associated with roads is therefore an important, complementary component to proper management of vegetation for terrestrial vertebrates.
6. Describe the broad-scale implications for managing terrestrial vertebrates whose source habitats have undergone long-term decline, or for terrestrial vertebrates whose habitats or populations are negatively affected by one or more factors associated with roads. Management implications are broad-scale considerations about the potential to conserve or restore source habitats, or to manage human access and human activities, on FS- and BLM-administered lands in response to habitat decline or to negative effects of human disturbance. Describe these implications from results of our assessment, from the scientific literature, and from results of prior assessments conducted as part of the ICBEMP. Whenever possible, link these implications to specific geographic areas of the basin based on our spatial assessment of source habitats and our mapping of broad-scale patterns of road density.

As part of management implications, we listed broad-scale strategies and practices that may be useful to managers seeking to conserve and restore habitats that have undergone long-term decline. This list should be considered a menu of possible approaches that managers could adopt to help achieve their objectives for

conservation and restoration of habitats. Before any of these approaches are adopted, they should be analyzed to determine their effectiveness, their compatibility with overall ecosystem management objectives, and their applicability to local situations. If any of these strategies are used, it is particularly important that testing and validation continue at all geographic scales of their implementation. We assumed that each local situation will be analyzed to determine if the strategies identified as part of our assessment will have the intended effects and be compatible with other land management objectives and activities.

Following this logic, our objectives did not call for an assessment of potential strategies in terms of their effect on the habitat outcomes of Lehmkuhl and others (1997) because it is expected that managers will adopt unique sets of strategies in response to various legal, social, and economic considerations that are beyond the scope of this paper. Spatially explicit strategies, developed by managers of BLM- and FS-administered lands, could be assessed at a later date in terms of their adequacy to comply with laws such as ESA and NFMA.

Related Assessments

Our assessment was designed to complement results from previous scientific assessments conducted for the ICBEMP, particularly the work by Quigley and others (1996), Hann and others (1997), Lee and others (1997), Lehmkuhl and others (1997), Marcot and others (1997), and Hessburg and others (1999). Hann and others (1997) characterized landscape conditions within the basin, historically (mid to late 19th century) and currently (late 20th century), in terms of vegetation, succession, and disturbance regimes using a large mapping unit (pixel size) of 100 ha (247 acres), broad-scale methods of spatial analysis, and complete sampling coverage. Hessburg and others (1999) also characterized landscape conditions within the basin, but did so at a finer scale (mapping unit of 4 ha [10 acres]), over a different time period (early or mid 1900s to late 1900s), and using samples taken from <5 percent of the land base. Lee and others (1997) characterized aquatic conditions within the basin, particularly in terms of cold-water fisheries. Marcot and others (1997) catalogued the terrestrial plant and animal taxa occurring within the basin, particularly in terms of the number of species, their distributions,

their ecological functions and roles, and their environmental correlates. Marcot and others (1997) also mapped several broad-scale spatial patterns related to biological diversity, such as hotspots and centers of endemism. Lehmkuhl and others (1997) assessed habitat outcome of selected terrestrial plant and animal species, historically, currently, and under each of the alternatives proposed in the DEIS (USDA Forest Service and USDI Bureau of Land Management 1997a, 1997b). Finally, Quigley and others (1996) integrated results from the above assessments in a spatially explicit manner at the scale of the subbasin. Integration focused primarily on combining estimates of ecological integrity from landscape, aquatic, and socioeconomic resources, and mapping the combined results across subbasins in the form of six classes of forest and six classes of rangeland clusters, with each class depicting a different level of ecological condition (Quigley and others 1996). Concise summaries of these prior science assessments for the ICBEMP are described by Hann and others (1998), Haynes and others (1998), Lee and others (1998), and Raphael and others (1998). Noss and others (1995) also described habitat trends for the basin and other areas of the United States.

In contrast to these prior assessments, our assessment was intended to be a broad-scale analysis of macro-habitat conditions across the basin for a targeted set of terrestrial vertebrates. Results of our assessment were intended to be integrated with information on landscape conditions, aquatic resources, and socioeconomic patterns to refine our composite knowledge of ecological risk and opportunity throughout the basin. Results of our assessment also were assumed to lead to finer scale evaluations of habitats for some groups or species as part of implementation procedures. Implementation procedures were necessary to relate our findings to local conditions as part of the management application process.

Study Area

Our assessment covered the basin east of the crest of the Cascade Range and those portions of the Klamath and Great Basins within Oregon (fig. 1A). The 58-million-ha (145-million-acre) basin (fig. 1A) is stratified into four spatial scales (Gravenmier and others 1997): (1) ecological reporting unit (ERU), (2) subbasin, (3) watershed, and (4) subwatershed. Ecological reporting units, of which there are 13 (fig. 1B), range

in size from about 740 000 to 6 800 000 ha (1,829,000 to 16,800,000 acres; mean size of about 2 375 000 ha [5,866,250 acres]). The 164 subbasins, or 4th hydrologic unit code (HUC), average about 345 000 ha (850,000 acres), whereas the 2,562 watersheds, or 5th HUCs, average about 22 500 ha (56,000 acres) each. The 7,654 subwatersheds (6th HUCs) average about 7700 ha (19,000 acres). Quigley and others (1996) described these spatial scales and the diverse ecological components of the basin in detail. Marcot and others (1997) further described flora and fauna occurring within the basin.

Methods

Several large-scale, ecosystem-based assessments have been completed recently (Anonymous 1996, USDA Forest Service and USDI Bureau of Land Management 1994, SAMAB 1996), yet few standard methods exist for evaluating terrestrial species and their habitats at a broad scale. Moreover, even fewer methods exist for developing an analysis framework in which broad-based management strategies can be established for holistic management of a large complex of terrestrial vertebrates. Efforts have been made to develop broad-scale methods to identify areas having little management protection and high species richness, such as gap analysis (Kiester and others 1996, Scott and others 1993). Less attention has been devoted, however, to the problems of identifying historical changes in habitats and to the challenges of developing spatially explicit themes to correct problems caused by long-term, negative changes in those habitats. Consequently, our methods were designed to meet unique objectives. Previous, broad-scale methods of habitat assessment, such as those used by Kiester and others (1996), Marcot and others (1997), and Scott and others (1993), relied on estimates of species occurrence in relation to current habitat conditions. Our methods build on these but were also designed to meet objectives that called for identifying only those habitats that presumably contribute to stationary or positive population growth (source habitats), and that required measurement of temporal change in such habitats from historical to current conditions. Consequently, our broad-scale methods differ from broad-scale approaches adopted elsewhere.

Given this background, the major steps of our analysis were (1) identifying species on which to focus the analysis; (2) delineating species ranges; (3) determining the relation of species with source habitats;

(4) designing a hierarchical system of single- and multi-species assessment; (5) clustering the species into groups, based on similarities in source habitats; (6) assessing change in source habitats from historical to current conditions for species and groups; (7) forming families of groups to summarize results among multiple groups; (8) correlating change in source habitats among species within groups and families to verify how well group and family trends reflected trends of individual species; (9) summarizing knowledge about species-road relations; (10) mapping road density in relation to abundance of source habitats for selected species; (11) interpreting results and identifying broad-scale management implications for those species, groups, and families whose source habitats have undergone long-term decline, or for those species whose populations or habitats are negatively affected by factors associated with roads; and (12) validating agreement between change in source habitats and trends in viability that were projected by Lehmkuhl and others (1997). Following are the specific methods used for each step.

Identifying Species of Focus

We used seven criteria to develop an initial list of species that were the focus of our assessment. Most of these criteria were based on results of the assessment of species-habitat conditions under planning alternatives (Lehmkuhl and others 1997) that were developed for the basin as part of the DEIS (USDA Forest Service and USDI Bureau of Land Management 1997a, 1997b). The process used by Lehmkuhl and others (1997) defined five classes of habitat outcome that were possible for each species (fig. 2). The five outcome classes were defined as follows: outcome 1—habitat broadly distributed with opportunity for nearly continuous distribution of the species; outcome 2—habitat broadly distributed but with gaps; patches large or close enough to permit dispersal; outcome 3—habitat primarily in patches, some of which are small or isolated, causing limitations in species dispersal; outcome 4—habitat in isolated patches with strong limitations on dispersal; some likelihood of local extirpation; and outcome 5—habitat scarce with little or no opportunity for dispersal among patches and strong likelihood of extirpation.

Expert panels were used to assess the likelihood that these conditions existed for each species historically, currently, and under the future scenarios projected for

5. Species that were the subject of the petition filed by the Natural Resources Defense Council with the Regional Forester of the Pacific Northwest Region, USDA Forest Service, on March 30, 1993. Other species that were the subject of repeated appeals to either the FS or the BLM within the jurisdictions of the basin also were included.
6. Species for which The Nature Conservancy assigned a Global ranking of 1 or 2.
7. Species added by the expert panel process that was conducted for terrestrial habitat assessment during September 1997. Some of the species added during this process were not evaluated by Lehmkuhl and others (1997).

We reviewed the initial species list developed from this set of criteria to ensure that it included species associated with all source habitats that were declining, or thought to be declining. We also reviewed the initial list to ensure that it included species whose source habitats were not only declining, but whose population or habitat status was identified as requiring coordination across administrative units of the FS and BLM. The list was reviewed again by panels of species experts to ensure that it included all species of potential concern within the basin as part of criterion 7 described above.

Application of these seven criteria resulted in a final list of 91 species whose source habitats could be mapped reliably by using a pixel size of 100 ha (247 acres), as determined by expert panels (table 1). These species, referred to as broad-scale species of focus, composed our broad-scale analysis. Additional species (>80), most of which were deemed to be dependent on riparian or water habitats, also met the seven criteria (table 1); source habitats for these species, however, were identified by experts as needing mapping units smaller than 100 ha (247 acres) to reliably estimate their habitat abundance.

Again, it is important to note that our species list (table 1) was intended to be inclusive rather than exclusive and to help focus our analysis on ecosystem conditions. It should not be interpreted as a list of species representing some critical legal or biological threshold.

Delineating Species Ranges

We used range maps developed by Marcot and others (in prep.) to estimate the inclusive geographic area that was occupied historically and currently by each species of focus. Range maps were drawn by using the following criteria:

- For broadly distributed species, range maps were drawn to simply reflect the outer extent of the occurrence of the species. Consequently, these maps include large areas of both used and unused habitats.
- For common species with disjunct populations, range maps were drawn to reflect the outer extent of each individual population.
- For locally endemic species or species with small, scattered populations, range maps were drawn to reflect known and potential areas occupied by the species.
- For species whose range is known to have shifted significantly from historical conditions (as defined by Marcot and others, in prep.), separate maps were developed for current and historical range. For all other species, maps that delineate the current range by definition also denote the historical range.
- Maps of each species range were drawn only for areas within the boundaries of the basin because our evaluation was restricted to the basin. When interpreting results of our analyses, however, in combination with population and habitat data available from other studies, we typically considered the entire range of a species if it potentially affected our interpretations.

Information used to develop range maps included previously published maps and published and unpublished location data (Marcot and others, in prep.). Maps were drawn with the help of species experts and subsequently reviewed by these experts to ensure that the final map of the range of each species adhered to the above criteria.

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected

Class ^a	Common name	Scientific name	Scale ^b	Criteria								Adjust ^j	Add ^k
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ			
R	Mojave black-collared lizard	<i>Crotaphytus bicinctores</i>	BS			X							
R	Longnose leopard lizard	<i>Gambelia wislizenii</i>	BS	X	X	X							
R	Sharptail snake	<i>Contia tenuis</i>	BS	X	X	X	X					X	
R	Striped whipsnake	<i>Masticophis taeniatus</i>	BS	X	X	X							
R	California mountain kingsnake	<i>Lampropeltis zonata</i>	BS					X					
R	Longnose snake	<i>Rhinocheilus lecontei</i>	BS					X					
R	Ground snake	<i>Sonora semiannulata</i>	BS					X					
B	Northern goshawk	<i>Accipiter gentilis</i>	BS		X	X			X				
B	Ferruginous hawk	<i>Buteo regalis</i>	BS		X	X	X						
B	Blue grouse	<i>Dendrogapus obscurus</i>	BS										X
B	Sage grouse	<i>Centrocercus urophasianus</i>	BS		X	X	X						
B	Columbian sharp-tailed grouse	<i>Tympanuchus phasianellus columbianus</i>	BS		X	X	X						
B	Mountain quail	<i>Oreortyx pictus</i>	BS	X	X	X							
B	Flammulated owl	<i>Otus flammeolus</i>	BS		X	X	X		X				
B	Burrowing owl	<i>Athene cunicularia</i>	BS		X	X							
B	Great gray owl	<i>Strix nebulosa</i>	BS	X	X	X	X		X				
B	Long-eared owl	<i>Asio otus</i>	BS	X	X	X							
B	Short-eared owl	<i>Asio flammeus</i>	BS										X
B	Boreal owl	<i>Aegolius funereus</i>	BS	X	X	X	X						
B	Vaux's swift	<i>Chaetura vauxi</i>	BS	X	X	X	X		X			X	
B	Rufous hummingbird	<i>Selasphorus rufus</i>	BS			X	X						X
B	Black-chinned hummingbird	<i>Archilochus alexandri</i>	BS			X							
B	Broad-tailed hummingbird	<i>Selasphorus platycercus</i>	BS		X	X							
B	Lewis' woodpecker	<i>Melanerpes lewis</i>	BS		X	X	X						
B	Williamson's sapsucker	<i>Sphyrapicus thyroideus</i>	BS		X	X	X						
B	White-headed woodpecker	<i>Picoides albolarvatus</i>	BS		X	X	X		X			X	
B	Three-toed woodpecker	<i>Picoides tridactylus</i>	BS			X	X		X				
B	Black-backed woodpecker	<i>Picoides arcticus</i>	BS		X	X	X		X				
B	Pileated woodpecker	<i>Dryocopus pileatus</i>	BS	X	X	X	X		X			X	
B	Olive-sided flycatcher	<i>Contopus cooperi</i>	BS		X	X							
B	Hammond's flycatcher	<i>Empidonax hammondi</i>	BS		X	X	X						

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected (continued)

Class ^a	Common name	Scientific name	Scale ^b	Criteria								
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ	Adjust ^j	Add ^k
B	Ash-throated flycatcher	<i>Myiarchus cinerascens</i>	BS			X	X					
B	Chestnut-backed chickadee	<i>Parus rufescens</i>	BS	X	X	X	X					
B	Bushtit	<i>Psaltriparus minimus</i>	BS	X		X	X					
B	White-breasted nuthatch	<i>Sitta carolinensis</i>	BS			X	X		X			
B	Pygmy nuthatch	<i>Sitta pygmaea</i>	BS			X	X		X			
B	Brown creeper	<i>Certhia americana</i>	BS									X
B	Winter wren	<i>Troglodytes troglodytes</i>	BS		X	X	X					
B	Golden-crowned kinglet	<i>Regulus satrapa</i>	BS									X
B	Western bluebird	<i>Sialia mexicana</i>	BS			X	X					
B	Varied thrush	<i>Ixoreus naevius</i>	BS									X
B	Sage thrasher	<i>Oreoscoptes montanus</i>	BS			X	X					
B	Loggerhead shrike	<i>Lanius ludovicianus</i>	BS			X	X					
B	Hermit warbler	<i>Dendroica occidentalis</i>	BS					X				
B	Lazuli bunting	<i>Passerina amoena</i>	BS/FS			X						
B	Clay-colored sparrow	<i>Spizella pallida</i>	BS					X				
B	Brewer's sparrow	<i>Spizella breweri</i>	BS			X	X					
B	Vesper sparrow	<i>Pooecetes gramineus</i>	BS				X					
B	Lark sparrow	<i>Chondestes grammacus</i>	BS			X	X					
B	Black-throated sparrow	<i>Amphispiza bilineata</i>	BS					X				
B	Sage sparrow	<i>Amphispiza belli</i>	BS				X					
B	Lark bunting	<i>Calamospiza melanocorys</i>	BS									X
B	Grasshopper sparrow	<i>Ammodramus savannarum</i>	BS	X	X	X						
B	Western meadowlark	<i>Sturnella neglecta</i>	BS									X
B	Brown-headed cowbird	<i>Molothrus ater</i>	BS									X
B	Black rosy finch	<i>Leucosticte atrata</i>	BS	X	X	X						
B	Gray-crowned rosy finch	<i>Leucosticte tephrocotis</i>	BS	X	X	X						
B	White-winged crossbill	<i>Loxia leucoptera</i>	BS			X						
B	Pine siskin	<i>Carduelis pinus</i>	BS									X
M	Preble's shrew	<i>Sorex preblei</i>	BS					X				
M	Pygmy shrew	<i>Sorex hoyi</i>	BS					X				
M	Yuma myotis	<i>Myotis yumanensis</i>	BS					X				
M	Long-eared myotis	<i>Myotis evotis</i>	BS		X	X					X	

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected (continued)

Class ^a	Common name	Scientific name	Scale ^b	Criteria									Adjust ^j	Add ^k
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ				
M	Fringed myotis	<i>Myotis thysanodes</i>	BS		X	X	X					X		
M	Long-legged myotis	<i>Myotis volans</i>	BS		X	X	X					X		
M	Western small-footed myotis	<i>Myotis ciliolabrum</i>	BS		X	X	X					X		
M	Silver-haired bat	<i>Lasionycteris noctivagans</i>	BS		X	X	X					X		
M	Hoary bat	<i>Lasiurus cinereus</i>	BS		X	X	X					X		
M	Spotted bat	<i>Euderma maculatum</i>	BS	X	X	X						X		
M	Townsend's big-eared bat	<i>Corynorhinus townsendii</i>												
		<i>pallescens</i>	BS	X	X	X						X		
M	Pallid bat	<i>Antrozous pallidus</i>	BS										X	
M	Pygmy rabbit	<i>Brachylagus idahoensis</i>	BS	X	X	X								
M	Idaho ground squirrel	<i>Spermophilus brunneus</i>	BS					X						
M	White-tailed antelope squirrel	<i>Ammospermophilus leucurus</i>	BS					X						
M	Washington ground squirrel	<i>Spermophilus washingtoni</i>	BS					X		G2				
M	Wyoming ground squirrel	<i>Spermophilus elegans</i>	BS										X	
M	Uinta ground squirrel	<i>Spermophilus armatus</i>	BS					X						
M	Western gray squirrel	<i>Sciurus griseus</i>	BS					X						
M	Northern flying squirrel	<i>Glaucomys sabrinus</i>	BS		X	X	X					X		
M	Sagebrush vole	<i>Lemmys curtatus</i>	BS										X	
M	Gray wolf	<i>Canis lupus</i>	BS										X	
M	Kit fox	<i>Vulpes macrotis</i>	BS					X						
M	Grizzly bear	<i>Ursus arctos</i>	BS		X	X								
M	American marten	<i>Martes americana</i>	BS		X	X	X		X			X		
M	Fisher	<i>Martes pennanti</i>	BS	X	X	X	X		X			X		
M	Wolverine	<i>Gulo gulo</i>	BS		X	X			X			X		
M	Lynx	<i>Lynx canadensis</i>	BS		X	X			X			X		
M	Woodland caribou	<i>Rangifer tarandus caribou</i>	BS	X	X	X								
M	Pronghorn	<i>Antilocapra americana</i>	BS		X	X	X					X		
M	Mountain goat	<i>Oreamnos americanus</i>	BS										X	
M	California bighorn sheep	<i>Ovis canadensis californiana</i>	BS	X	X	X								
M	Rocky Mountain bighorn sheep	<i>Ovis canadensis canadensis</i>	BS										X	
A	Coeur d'Alene salamander	<i>Plethodon idahoensis</i>	FS	X	X	X						X		
A	Larch mountain salamander	<i>Plethodon larselli</i>	FS					X		G2				

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected (continued)

Class ^a	Common name	Scientific name	Scale ^b	Criteria								
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ	Adjust ^j	Add ^k
A	Idaho giant salamander	<i>Dicamptodon aterrimus</i>	FS					X				
A	Tailed frog	<i>Ascaphus truei</i>	FS	X	X	X	X					
A	Western toad	<i>Bufo boreas</i>	FS		X	X	X				X	
A	Woodhouse's toad	<i>Bufo woodhousii</i>	FS	X	X	X	X					
A	Northern leopard frog	<i>Rana pipiens</i>	FS	X	X	X	X				X	
A	Columbian spotted frog	<i>Rana luteiventris</i>	FS	X	X	X					X	
A	Oregon spotted frog	<i>Rana pretiosa</i>	FS		X	X					X	
R	Western pond turtle	<i>Clemmys marmorata</i>	FS			X						
R	Painted turtle	<i>Chrysemys picta</i>	FS			X	X					
R	Rubber boa	<i>Charina bottae</i>	FS	X	X	X	X					
R	Common garter snake	<i>Thamnophis sirtalis</i>	FS			X	X					
B	Common loon	<i>Gavia immer</i>	FS	X	X	X						
B	Red-necked grebe	<i>Podiceps grisegena</i>	FS	X	X	X						
B	Western grebe	<i>Aechmophorus occidentalis</i>	FS	X	X	X						
B	Clark's grebe	<i>Aechmophorus clarkii</i>	FS	X	X	X						
B	American white pelican	<i>Pelecanus erythrorhynchos</i>	FS	X	X	X						
B	American bittern	<i>Botaurus lentiginosus</i>	FS	X	X	X						
B	Western least bittern	<i>Ixobrychus exilis hesperis</i>	FS	X	X	X						
B	Great blue heron	<i>Ardea herodias</i>	FS	X	X	X						
B	Great egret	<i>Ardea alba</i>	FS	X	X	X						
B	Snowy egret	<i>Egretta thula</i>	FS	X	X	X						
B	Black-crowned night heron	<i>Nycticorax nycticorax</i>	FS	X	X	X						
B	White-faced ibis	<i>Plegadis chihi</i>	FS	X	X	X						
B	Trumpeter swan	<i>Cygnus buccinator</i>	FS	X	X	X						
B	Wood duck	<i>Aix sponsa</i>	FS	X	X	X						
B	Green-winged teal	<i>Anas crecca</i>	FS		X	X						
B	Mallard	<i>Anas platyrhynchos</i>	FS		X	X						
B	Northern pintail	<i>Anas acuta</i>	FS		X	X						
B	Blue-winged teal	<i>Anas discors</i>	FS		X	X						
B	Cinnamon teal	<i>Anas cyanoptera</i>	FS		X	X						
B	Northern shoveler	<i>Anas clypeata</i>	FS		X	X						
B	Gadwall	<i>Anas strepera</i>	FS		X	X						

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected (continued)

Class ^a	Common name	Scientific name	Scale ^b	Criteria								
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ	Adjust ^j	Add ^k
B	American wigeon	<i>Anas americana</i>	FS		X	X						
B	Canvasback	<i>Aythya valisineria</i>	FS	X	X	X						
B	Redhead	<i>Aythya americana</i>	FS	X	X	X						
B	Ring-necked duck	<i>Aythya collaris</i>	FS	X	X	X						
B	Lesser scaup	<i>Aythya affinis</i>	FS	X	X	X						
B	Harlequin duck	<i>Histrionicus histrionicus</i>	FS	X	X	X	X					
B	Common goldeneye	<i>Bucephala clangula</i>	FS	X	X	X						
B	Barrow's goldeneye	<i>Bucephala islandica</i>	FS	X	X	X						
B	Bufflehead	<i>Bucephala albeola</i>	FS	X	X	X						
B	Hooded merganser	<i>Lophodytes cucullatus</i>	FS	X	X	X						
B	Common merganser	<i>Mergus merganser</i>	FS	X	X	X						
B	Ruddy duck	<i>Oxyura jamaicensis</i>	FS	X	X	X						
B	Bald eagle	<i>Haliaeetus leucocephalus</i>	FS		X	X	X					
B	Yellow rail	<i>Coturnicops noveboracensis</i>	FS					X				
B	Virginia rail	<i>Rallus limicola</i>	FS	X	X	X						
B	Sora	<i>Porzana carolina</i>	FS	X	X	X						
B	Greater sandhill crane	<i>Grus canadensis tabida</i>	FS	X	X	X						
B	Western snowy plover	<i>Charadrius alexandrinus nivosus</i>	FS	X	X	X						
B	Black-necked stilt	<i>Himantopus mexicanus</i>	FS	X	X	X						
B	American avocet	<i>Recurvirostra americana</i>	FS	X	X	X						
B	Willet	<i>Catoptrophorus semipalmatus</i>	FS	X	X	X						
B	Spotted sandpiper	<i>Actitis macularia</i>	FS									X
B	Upland sandpiper	<i>Bartramia longicauda</i>	FS		X	X						
B	Long-billed curlew	<i>Numenius americanus</i>	FS	X	X	X						
B	Common snipe	<i>Gallinago gallinago</i>	FS		X	X						
B	Wilson's phalarope	<i>Phalaropus tricolor</i>	FS									X
B	Forster's tern	<i>Sterna forsteri</i>	FS	X	X	X						
B	Black tern	<i>Chlidonias niger</i>	FS	X	X	X						
B	Yellow-billed cuckoo	<i>Coccyzus americanus</i>	FS	X	X	X						
B	Western screech owl	<i>Otus kennicottii</i>	FS			X						
B	Red-naped sapsucker	<i>Sphyrapicus nuchalis</i>	FS		X	X	X					
B	Downy woodpecker	<i>Picoides pubescens</i>	FS			X	X					

Table 1—Common and scientific names of 173 terrestrial vertebrate species of focus brought forward for additional analysis and the associated criteria by which each species was selected (continued)

Class ^a	Common name	Scientific name	Scale ^b	Criteria								
				<90H ^c	<90C ^d	<90A ^e	EIS SIG ^f	Fine ^g	NRDC ^h	G1G2 ⁱ	Adjust ^j	Add ^k
B	Willow flycatcher	<i>Empidonax traillii</i>	FS		X	X						
B	Least flycatcher	<i>Empidonax minimus</i>	FS					X				
B	Veery	<i>Catharus fuscescens</i>	FS		X	X						
B	Red-eyed vireo	<i>Vireo olivaceus</i>	FS	X	X	X						
B	Virginia's warbler	<i>Vermivora virginiae</i>	FS									X
B	Yellow warbler	<i>Dendroica petechia</i>	FS		X	X						
B	American redstart	<i>Setophaga ruticilla</i>	FS									X
B	Wilson's warbler	<i>Wilsonia pusilla</i>	FS	X	X	X						
B	Yellow-breasted chat	<i>Icteria virens</i>	FS		X	X						
B	Fox sparrow	<i>Passerella iliaca</i>	FS									X
B	Bobolink	<i>Dolichonyx oryzivorus</i>	FS	X	X	X						
B	Tricolored blackbird	<i>Agelaius tricolor</i>	FS					X				
B	Brewer's blackbird	<i>Euphagus cyanocephalus</i>	FS									X
M	Water shrew	<i>Sorex palustris</i>	FS					X				
M	Water vole	<i>Microtus richardsoni</i>	FS									X
M	Northern bog lemming	<i>Synaptomys borealis</i>	FS					X				

^a B = bird, M = mammal, R = reptile, and A = amphibian.

^b BS = broad-scale species of focus assessed in this paper. Ninety-one species were identified as broad-scale vertebrates of focus, whose source habitats could reliably be evaluated by using a mapping unit (pixel size) of 100 ha (254 acres). FS = fine-scale species of focus whose source habitats require mapping units <100 ha (254 acres).

^c <90H = habitat outcome score (from Lehmkuhl and others 1997) <90 points in the added scores of outcomes 1, 2, and 3 for the historical time period, BLM and FS lands only.

^d <90C = habitat outcome score (from Lehmkuhl and others 1997) <90 points in the added scores of outcomes 1, 2, and 3 for the current time period, BLM and FS lands only.

^e <90A = habitat outcome score (from Lehmkuhl and others 1997) <90 points in the added scores of outcomes 1, 2, and 3 for any of the 7 alternatives (BLM and FS lands only) described in either the draft eastside EIS (USDA Forest Service and USDI Bureau of Land Management 1997a) or draft upper Columbia River basin EIS (USDA Forest Service, USDI Bureau of Land Management 1997b).

^f EIS SIG = the weighted mean outcome score in any one of the alternatives (BLM and FS lands only) increased or decreased by more than 0.5 points from the current outcome score, a significant change according to the EIS teams.

^g Fine = species for which Lehmkuhl and others (1997) did not complete an analysis for the outcome assessment because of the restricted distribution of these species within the basin. These species ranges are predominately outside the basin.

^h NRDC = species that were the subject of the petition filed by the Natural Resources Defense Council with the Regional Forester, Pacific Northwest Region, USDA Forest Service, on March 30, 1993.

ⁱ G1G2 = species listed by the Natural Heritage program as Global Rank 1 or Global Rank 2.

^j Adjust = species for which panelists' scores were adjusted by the science team (Lehmkuhl and others 1997). Scores were adjusted when considered to reflect a misinterpretation or incomplete understanding of the management alternatives or their outcomes, or the species' ecology.

^k Add = species added by terrestrial habitat panelists (vol. 3, appendix 2) during September 1997 due to concerns about habitat or population status. Some of these species were not evaluated in the prior outcome assessment by Lehmkuhl and others (1997).

Determining Species Relations With Source Habitats

Vegetation classification system used to define source habitats—We used the vegetation classification system of cover types and structural stages that was derived for broad-scale vegetation assessments of the ICBEMP (Hann and others 1997) as the basis for defining source habitats for each species of focus. We used this system because (1) it is the standard classification system that was developed to characterize the composition and structure of vegetation at the broad scale within the basin; (2) this system was created specifically to characterize broad-scale patterns of disturbance regimes and succession dynamics over a diverse array of forest and rangeland conditions, at large spatial scales, and over long periods of time; and (3) our results are intended to be integrated with results from all other broad-scale scientific assessments of the ICBEMP, all of which have used this system (for example, see assessments for landscape ecology [Hann and others 1997] and aquatic resources [Lee and others 1997]). Below is a detailed description of the methods used to estimate composition and structure of vegetation under this broad-scale system of classification.

Estimating and validating occurrence of cover types and structural stages for broad-scale assessment—Maps of vegetation cover types (CT) and structural stages (ST) were derived originally as part of the Columbia River basin succession model (CRBSUM) (Keane and others 1996) for broad-scale assessment of vegetation in the basin. The CRBSUM specifically was built to map the composition and structure of vegetation for historical and current periods, accounting for coarse-scale disturbance regimes and succession dynamics (Hann and others 1997, Keane and others 1996). As part of this process, cover types were developed to estimate the plant species that characterize the vegetative composition of a mapping unit, with the mapping unit defined as a pixel or cell of 1 km² (0.4-mi²) at the broad scale. Examples of cover types mapped at this cell size include lodgepole pine, western larch, and whitebark pine for forested environments and big sagebrush, native forb, and juniper/sagebrush for rangeland environments (Hann and others 1997). By contrast, structural stages were developed to estimate the structural conditions of plant species that characterize a mapping unit of 1 km² (0.4-mi²). Examples of structural stages mapped

at this scale include stand initiation, understory reinitiation, and old-forest single-story for forested environments and open herbland, closed low-medium shrub, and open tall shrub for rangeland environments (Hann and others 1997).

Methods for deriving the initial estimates of the cover types and structural stages were described by Hann and others (1997) and Menakis and others (1996). Initial estimates of CT and ST were then mapped and rectified with each other and with the CRBSUM potential vegetation type (PVT) map as part of the classification and modeling process (Menakis and others 1996). The PVTs are classes of biophysical environments based on combinations of climate, terrain, and soil that are labeled by plant species, with the labels serving as indicators of the kind of environmental conditions present (Hann and others 1997). Indicator plants used to name the PVT are often not the plant species name of the CT because of disturbances, succession, and exotic plant invasions that result in dominance by other species. For example, ponderosa pine is a common CT in the Douglas-fir PVTs in environments where fire has been frequent historically, which is part of the native regime. Cheatgrass, an exotic plant species, is a common CT in sagebrush PVTs in dry environments, typically in conjunction with a combination of excessive livestock grazing and increased frequency of fire (Hann and others 1997), which is not part of the native regime. The PVTs have been grouped into potential vegetation groups (PVGs) such as forest, dry shrub, and agriculture.

Rectification among CT, ST, and PVT estimates was conducted to ensure that CTs and STs would only occur on sites that had the successional potential to produce those CTs and STs (Menakis and others 1996). This not only improved broad-scale accuracy, but also met the logic conditions for simulating succession and disturbance dynamics with the CRBSUM. For example, if a ponderosa pine CT occurred with an open herbland ST on a whitebark pine/subalpine larch north PVT, an obvious problem existed with the input data. Many combinations of CT/ST/PVT, however, had potential errors that were more subtle. The CRBSUM contained a logic-checking routine that compared the CT/ST/PVT combinations with the successional pathways of combinations of CT/ST that could occur in a given PVT. A rule set was established for correcting logic errors. In general, the PVT input map was more accurate than the CT and ST maps because of its direct relation to biophysical characteristics. Consequently, if an error was detected, the CT

or ST typically was changed to be consistent with the PVT. In some instances, however, certain CTs had high predictive reliability; in these cases, the CTs were used to identify a need to correct some of the PVTs.

The CRBSUM maps for the current period were designed to reflect average conditions for the decade 1985 to 1995 (Hann and others 1997). Two input maps were used to develop the CRBSUM CT map. Hardy and others (1996) provided a broad classification of cover types through use of 1-km² (0.4-mi²) satellite imagery. A land cover characterization (LCC) map for the United States provided an additional source for broad cover types (Eidenshink 1992, Loveland and others 1991). These two maps were refined by ecologists during several ICBEMP workshops and used to develop the final input map (Menakis and others 1996). This final map was then refined based on the CRBSUM logic-checking process described above and in Menakis and others (1996).

The current period CRBSUM ST map was developed by using a statistical analysis of current mid-scale subwatershed sample data from Hessburg and others (1999) that was aggregated to a 1-km² (0.4-mi²) scale (Menakis and others 1996). The ST data from the subwatershed sample were correlated with other 1-km² (0.4 mi²) scale data, such as CT, PVT, ownership, and road density, and then extrapolated with a statistical function across all 1-km² (0.4-mi²) cells of the basin. This ST map was then refined based on the CRBSUM logic-checking process (Menakis and others 1996).

The CRBSUM maps for the historical period were designed to reflect average conditions for the latter half of the 19th century (1850 to 1900) (Hann and others 1997). The CT input map for historical conditions was a vector map from Losensky (1994), derived from a compilation of late 1800s and early 1900s vegetation survey, potential land use, and military expedition maps. This CT map was then refined based on the CRBSUM logic-checking process (Menakis and others 1996).

The CRBSUM ST map for the historical period was developed from survey data supplied by Losensky (1994). These data were used to determine a ST composition by CT for each of the survey areas, and were then extrapolated across the basin within cover type and ecoregion stratifications (Menakis and others 1996). This ST map was then refined based on the

CRBSUM logic-checking process for combinations of CT, ST, and PVT described earlier (Menakis and others 1996).

The current and historical period CT, ST, and PVT data were compared with maps of cover types and structural stages estimated at the mid-scale (cell size of 4 ha [10 acres]) from aerial photos taken during the current period (1990s) and a more recent historical period (1930s to 1950s) that was the basis for the mid-scale analysis of Hessburg and others (1999) (Hann and others 1997, Menakis and others 1996). The more recent historical data from Hessburg and others (1999), which represent the mid-20th century estimate of CTs and STs at the mid-scale (4-ha [10-acre] cell size), do not represent the same time period as the historical period for broad-scale data; thus the mid-scale and broad-scale estimates of CTs and STs could not be compared directly. The mid-scale and broad-scale data used to estimate the current period, however, represent comparable periods. Results of comparisons between mid- and broad-scale estimates of CTs and STs for the current period are reported in Hann and others (1997) and Menakis and others (1996). Additional data used for assessment of accuracy of the broad-scale mapping included paired historic-current oblique photographs from Losensky (1995) and plot data that were used for the assessment of succession-disturbance regimes and general landscape patterns (Hann and others 1997).

Because maps of cover types and structural stages were produced at a 1-km² (0.4-mi²) (or 100 ha) scale as part of the development of CRBSUM, users should be aware of the implications of this large mapping scale. A 1-km² (0.4-mi²) cell is about 250 acres [somewhat larger than a 1/4 section (160 acres)]. Linear features such as roads, narrow riparian vegetation, and streams cannot be mapped at this scale. Cover types that occur in small patches of <4 ha (10 acres) and that have an average patch size less than one-fourth of the area of a 1-km² (0.4-mi²) cell also are not mapped. Cover types that occur in either large or small patches and that have an average patch size greater than one-fourth the area of a 1-km² (0.4-mi²) cell (that is, >25 ha or 62 acres), however, are typically mapped because some of these patches will be large enough to dominate a 1-km² (0.4-mi²) cell. Any 1-km² (0.4-mi²) cell has only about a 10- to 30-percent chance of being correctly typed, but about 65 to 95 percent of a large number of cells (for example, 100 or more cells) of the same type or of a group of types typically are

mapped correctly. The phenomenon of low probability of any one cell being correctly typed, but high probability of correctly typing a large number of cells of the same type, occurs for four reasons:

1. **High variation in number of types within the cell.** Mapping units composed of 1-km² (0.4-mi²) cells typically contain three to five different cover types that occur in patch sizes of about 4 ha (10 acres) or larger. A patch size of 4 ha (10 acres) is equivalent to the mapping unit used by Hessburg and others (1999) for the mid-scale landscape analysis of the basin, and is the size patch that generally can be detected as part of mapping at the broad-scale of 1 km² (0.4-mi²). Typically, the cover type with the largest area or greatest biomass dominates the characteristics of the cell. In many cases, the named type only covers 20 to 30 percent of the cell area, but it has the largest area and thus dominates the reflectance shown in the remote-sensed data source. In other cases, a forest type may compose less area than a nonforest type, but because of the large amount of biomass in forest types, the spectral reflectance may be dominated by the forest type. Accurate mapping of these types is dependent on the summary of many cells, which dampens the effect of high variation in cell composition.
2. **High variation in type distribution within cells.** Cover types that typically occur in small patches but are distributed abundantly and scattered throughout the cell also may dominate the characteristics of the cell. Accurate mapping of these types is dependent on summary of many cells or grouping of cover types, which again dampens the effect of high variation in type distribution within cells.
3. **Small sample size.** Cover types that occur in large patches, but that do not occur in many cells, will dominate the characteristics of those cells. Accurate mapping of these types is dependent on grouping of related types, which dampens the effect of small sample size.
4. **Cover types with similar characteristics.** Two or more cover types that have similar characteristics may dominate the characteristics of many cells. Accurate mapping of these types is dependent on finding accurate correlations with other mapped biophysical and human-caused characteristics.

This dampens effects of errors in misclassification to other cover types that have similar prediction characteristics.

These points provide context for understanding results of a formal assessment of mapping accuracy that was conducted to estimate the minimum-sized area (for example, subbasin or ERU) at which broad-scale data could be summarized to ± 10 percent confidence of the true estimate of the percentage of area occupied by cover types and structural stages (table 2). In general, groups of subbasins or an ERU were found to be appropriate levels at which to summarize the 1-km² (0.4-mi²) CT and ST data. Hann and others (1997) demonstrated that grouping similar CT and ST into physiognomic types or terrestrial communities substantially increased this accuracy. Results of this accuracy assessment (table 2) imply that use of CT and ST combinations to analyze source habitats for terrestrial vertebrates is not sufficiently accurate for making summaries at an individual subwatershed or watershed scale. Sufficient accuracy can be achieved, however, when base data for individual subwatersheds or watersheds are summarized to the larger scales of subbasin, ERU, or basin, by using base data from collections of subwatersheds or watersheds (table 2).

Building species-source habitat matrices—Marcot and others (1997) originally developed matrices of habitat associations for 547 vertebrate species occurring within the basin. These matrices included species associations with macrohabitats based on species occurrence, as well as species use of finer scale or nonvegetative features termed key environmental correlates. We used these data as a starting point to define source habitats and special habitat features for each species of focus. As noted earlier, source habitats are those characteristics of macrovegetation that contribute to stationary or positive population growth. Special habitat features are those nonvegetative factors or finer scale characteristics of vegetation that also contribute to stationary or positive population growth.

The habitat matrices of Marcot and others (1997) were based on slightly modified combinations of cover types and structural stages that were defined for macrovegetation of the basin (tables 3 and 4); methods used to estimate these cover types and structural stages at the broad scale were described in the previous section and described in further detail by Keane and others (1996), Menakis and others (1996), and

Table 2—Current and historical broad-scale cover type and structure vegetation maps with estimated accuracy

Map	Representative period	Method	Minimum area to achieve acceptable accuracy for codominant types	Minimum area to achieve acceptable accuracy across all types
Current cover type	1985-95	Correlation of ground truth with 1-km 1991 AVHRR satellite spectral class	Subbasin	Ecological reporting unit
Current structure	1985-95	Prediction model from correlation of mid-scale samples with broad-scale attributes	2-4 subbasins	Ecological reporting unit
Historical cover type	1850-1900	Vector mapping from late 1800s and early 1900s maps and records	3-6 subbasins	Ecological reporting unit
Historical structure	1850-1900	Cover type and ecoregion section random allocation of structure distribution from late 1800s and early 1900s records	5-10 subbasins	Ecological reporting unit
Current physiognomic types	1985-2005	Grouping of current cover types and structures based on similar response to succession and disturbance	Subbasin	2-3 subbasins
Historical physiognomic types	1800-1900	Grouping of historical cover types and structures based on similar response to succession and disturbance	2-3 subbasins	4-6 subbasins
Current physiognomic groups by PVG	1985-2005	Grouping of current physiognomic types by PVG	Watershed	2-3 watersheds
Historical physiognomic groups by PVG	1800-1900	Grouping of historical physiognomic types by PVG	2-3 watersheds	4-6 watersheds

Table 2—Current and historical broad-scale cover type and structure vegetation maps with estimated accuracy (continued)

Map	Representative period	Method	Minimum area to achieve acceptable accuracy for codominant types	Minimum area to achieve acceptable accuracy across all types
Current physiognomic group by PVG dominant patterns	1985-2005	Classes of uniform, mosaic, or mixed dominant composition patterns of physiognomic groups by PVG	Subwatershed	NA
Historical physiognomic group by PVG dominant patterns	1800-1900	Classes of uniform, mosaic, or mixed dominant composition patterns of physiognomic groups by PVG	Subwatershed	NA
Current terrestrial communities	1985-2005	Grouping of current cover types and structures based on similar terrestrial habitat characteristics	Subbasin	3-4 subbasins
Historical terrestrial communities	1800-1900	Grouping of historical cover types and structures based on similar terrestrial habitat characteristics	3-4 subbasins	6-8 subbasins

NA = not applicable.

Hann and others (1997). We expanded these estimates of macrovegetation to include two different types of structural stages for young forests: managed young forest and unmanaged young forest (tables 3 and 4). This expansion was important because the young-forest structural stage can differ widely in the density of large snags and legacy trees (Hann and others 1997). Moreover, differences in the densities of snags and legacy trees presumably affect survival of several cavity- and snag-dependent species (Thomas and others 1979), many of which we identified as species of focus. Managed young-forests, which we defined quantitatively in table 4, are young-forest structural

stages within areas that are roaded and with some history of timber harvest and fire exclusion (table 3.178, Hann and others 1997); these stands contain relatively few large snags and trees >53 cm (21 in) in diameter at breast height (d.b.h.) (table 3.178, Hann and others 1997). By contrast, unmanaged young forests, which we also defined quantitatively in table 4, are young-forest structural stages within areas that are unroaded, with fire exclusion and no history of timber harvest (table 3.178, Hann and others 1997); these stands contain relatively higher densities of large snags and trees (table 3.178, Hann and others 1997). In addition, for the purpose of our evaluation, we lumped the six structural stages of woodlands into one (table 4).

Table 3—Terrestrial community groups and terrestrial community types and their included cover types and structural stages as adapted from Hann and others (1997)

Terrestrial community group/type	Included cover types	Included structural stage codes ^a
Alpine:		
Alpine	Alpine tundra	Olms, Clms
Subalpine forest		
Late-seral subalpine single-layer forest	Whitebark pine	Ofs
Late-seral subalpine single-layer forest	Mountain hemlock	Ofs
Late-seral subalpine multi-layer forest	Whitebark pine	Ofm
Late-seral subalpine multi-layer forest	Whitebark pine-alpine larch	Ofm
Late-seral subalpine multi-layer forest	Engelmann spruce-subalpine fir	Ofm
Late-seral subalpine multi-layer forest	Mountain hemlock	Ofm
Mid-seral subalpine forest	Whitebark pine	UYf, MYf, Ur, Sec
Mid-seral subalpine forest	Whitebark pine-alpine larch	UYf, MYf, Ur, Sec
Mid-seral subalpine forest	Engelmann spruce-subalpine fir	UYf, MYf, Ur, Sec
Mid-seral subalpine forest	Mountain hemlock	UYf, MYf, Ur, Sec
Early-seral subalpine forest	Whitebark pine	Si
Early-seral subalpine forest	Whitebark pine-alpine larch	Si
Early-seral subalpine forest	Engelmann spruce-subalpine fir	Si
Early-seral subalpine forest	Mountain hemlock	Si
Montane forest:		
Late-seral montane single-layer forest	Western redcedar-western hemlock	Ofs
Late-seral montane single-layer forest	Interior Douglas-fir	Ofs
Late-seral montane single-layer forest	Western larch	Ofs
Late-seral montane single-layer forest	Lodgepole pine	Ofs
Late-seral montane single-layer forest	Grand fir-white fir	Ofs
Late-seral montane single-layer forest	Sierra Nevada mixed conifer	Ofs
Late-seral montane single-layer forest	Western white pine	Ofs
Late-seral montane multi-layer forest	Pacific silver fir-mountain hemlock	Ofm
Late-seral montane multi-layer forest	Western redcedar-western hemlock	Ofm
Late-seral montane multi-layer forest	Interior Douglas-fir	Ofm
Late-seral montane multi-layer forest	Western larch	Ofm
Late-seral montane multi-layer forest	Lodgepole pine	Ofm
Late-seral montane multi-layer forest	Red fir	Ofm
Late-seral montane multi-layer forest	Grand fir-white fir	Ofm
Late-seral montane multi-layer forest	Sierra Nevada mixed conifer	Ofm
Late-seral montane multi-layer forest	Western white pine	Ofm
Mid-seral montane forest	Pacific silver fir-mountain hemlock	UYf, MYf, Ur, Sec
Mid-seral montane forest	Western redcedar-western hemlock	UYf, MYf, Ur, Sec
Mid-seral montane forest	Interior Douglas-fir	UYf, MYf, Ur, Sec
Mid-seral montane forest	Western larch	UYf, MYf, Ur, Sec
Mid-seral montane forest	Lodgepole pine	UYf, MYf, Ur, Sec
Mid-seral montane forest	Red fir	UYf, MYf, Ur, Sec
Mid-seral montane forest	Grand fir-white fir	UYf, MYf, Ur, Sec
Mid-seral montane forest	Sierra Nevada mixed conifer	UYf, MYf, Ur, Sec
Mid-seral montane forest	Western white pine	UYf, MYf, Ur, Sec
Early-seral montane forest	Pacific silver fir-mountain hemlock	Si
Early-seral montane forest	Western redcedar-western hemlock	Si
Early-seral montane forest	Interior Douglas-fir	Si

Table 3—Terrestrial community groups and terrestrial community types and their included cover types and structural stages as adapted from Hann and others (1997) (continued)

Terrestrial community group/type	Included cover types	Included structural stage codes ^a
Early-seral montane forest	Western larch	Si
Early-seral montane forest	Lodgepole pine	Si
Early-seral montane forest	Red fir	Si
Early-seral montane forest	Grand fir-white fir	Si
Early-seral montane forest	Sierra Nevada mixed conifer	Si
Early-seral montane forest	Western white pine	Si
Early-seral montane forest	Shrub or herb/tree regeneration	Ots, Olms, Clms, Ch
Lower montane forest:		
Late-seral lower montane single-layer forest	Pacific ponderosa pine	Ofs
Late-seral lower montane single-layer forest	Interior ponderosa pine	Ofs
Late-seral lower montane multi-layer forest	Pacific ponderosa pine	Ofm
Late-seral lower montane multi-layer forest	Interior ponderosa pine	Ofm
Mid-seral lower montane forest	Pacific ponderosa pine	UYf, MYf, Ur, Sec
Mid-seral lower montane forest	Interior ponderosa pine	UYf, MYf, Ur, Seo, Sec
Early-seral lower montane forest	Pacific ponderosa pine	Si
Early-seral lower montane forest	Interior ponderosa pine	Si
Riparian woodland:		
Riparian woodland	Aspen	Ofm, UYf, MYf, Ur, Sec, Si
Riparian woodland	Cottonwood/willow	Ofm, UYf, MYf, Ur, Sec, Si
Upland woodland:		
Upland woodland	Limber pine	Wdl
Upland woodland	Juniper woodlands	Wdl
Upland woodland	Mixed-conifer woodlands	Wdl
Upland woodland	Juniper/sagebrush	Wdl
Upland woodland	Oregon white oak	Wdl
Upland shrubland:		
Upland shrubland	Chokecherry-serviceberry-rose	Ots, Olms, Clms
Upland shrubland	Mountain mahogany	Olms, Clms
Upland shrubland	Big sagebrush	Olms, Clms, Ch
Upland shrubland	Mountain big sagebrush	Olms, Clms
Upland shrubland	Low sage	Olms, Clms
Upland shrubland	Salt desert shrub	Olms, Clms
Upland shrubland	Antelope bitterbrush/bluebunch wheatgrass	Clms
Upland herbland:		
Upland herbland	Wheatgrass bunchgrass	Ch, Oh
Upland herbland	Fescue-bunchgrass	Ch, Oh
Upland herbland	Native forb	Ch, Oh
Riparian shrubland:		
Riparian shrubland	Shrub wetlands	Cts, Olms, Clms
Riparian herbland:		
Riparian herbland	Herbaceous wetlands	Ch, Oh
Exotic herbland:		
Exotic herbland	Exotic forbs-annual grass	Ch, Oh

Table 3—Terrestrial community groups and terrestrial community types and their included cover types and structural stages as adapted from Hann and others (1997) (continued)

Terrestrial community group/type	Included cover types	Included structural stage codes ^a
Agriculture:		
Agricultural	Cropland-hay-pasture	Ch, Oh
Rock:		
Rock/barren	Barren	
Urban:		
Urban	Urban	
Water:		
Water	Water	

^a Structural stage codes are defined in table 4.

The inclusion of these refined structural stages (table 4) with previous estimates of macrovegetation (Hann and others 1997) resulted in 157 cover type-structural stage combinations nested within 15 terrestrial community groups (table 3, fig. 3). Only those combinations of cover types and structural stages that plausibly occurred historically or that occur currently were used.

We also refined the seasons of use identified by Marcot and others (1997) because source habitats can function as breeding, rearing, migratory, or wintering areas. Consequently, source habitats were classified according to the seasonal functions that such habitats provide in supporting population persistence by using several broad categories. Species were first characterized as being either migratory or year-long residents of the basin. Migratory species were defined as species that spend part of the year outside the basin. Resident species were defined as species that live year-long within the basin.

For migratory species, we established three seasonal categories of habitat function: (1) **migrant breeding habitat**, defined as source habitat used for breeding or rearing in the basin by species that migrate seasonally to areas outside the basin; (2) **migrant wintering habitat**, defined as source habitat used for winter survival by species that reside within the basin during winter but breed elsewhere; and (3) **migrant migratory habitat**, defined as source habitat used for survival during migration through the basin by species that breed or winter elsewhere.

For resident species, we also established three categories of habitat function: (1) **resident summer habitat**, defined as source habitats used for survival or reproduction or rearing, or all three, late spring through early fall, by species who live year-long within the basin; (2) **resident winter habitat**, defined as source habitats used for survival during late fall through early spring by species that live year-long within the basin; and (3) **resident year-long habitat**, defined as source habitats used commonly throughout the year by a species to meet all seasonal life functions.

For species that depend on different source habitats in different seasons, a separate set of source habitat designations was indicated for each season based on the above system of classification. For resident species that depend on the same source habitats year-round, only one entry, resident year-long, was identified. For migrant species, those that were known to breed within the basin were always evaluated under the category of migrant breeding habitat; either of the other two categories (migrant wintering and migrant migratory habitats) was used only if the species was known not to breed within the basin, or if wintering or migratory habitat was deemed to constitute a different set of source habitats than those for breeding habitat.

Another variation in seasonal habitat function was used for one species, the Lewis' woodpecker. Experts identified two distinct populations, one migratory, the other resident. Accordingly, the migratory population of Lewis' woodpeckers was evaluated under the category of migrant breeding habitat; this population was deemed to occur throughout the range of the species

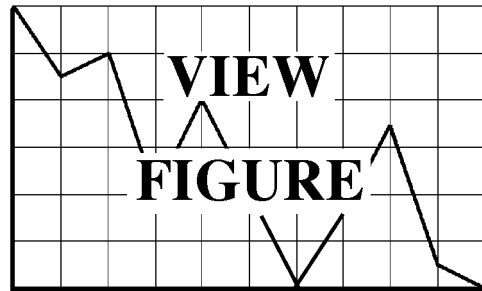


Figure 3—Illustration of forest structural stages defined in table 3 and in Hann and others (1997) that were used as part of methods to determine species relations with source habitats for 91 broad-scale species of focus.

Table 4—Structural stages defined for assessing the structural features of macrovegetation across the interior Columbia basin, as adapted from Hann and others (1997)

Structural stage	Structural stage code	Description ^a
Forest:		
Stand initiation	Si	LgT_cc <30% and SS_cc ≥10% and [(PT_cc + SmT_cc + MedT_cc <20%) or (PT_cc + SmT_cc + MedT_cc ≤60% and PT_cc + SmT_cc + MedT_cc ≥20% and SmT_cc + MedT_cc <10%)]
Stem-exclusion open canopy	Seo	LgT_cc <30% and SS_cc <10% and PT_cc + SmT_cc + MedT_cc ≤70%
Stem-exclusion closed canopy	Sec	LgT_cc <30% and SS_cc <10% and PT_cc + SmT_cc + MedT_cc >70%
Understory reinitiation	Ur	LgT_cc <30% and SS_cc ≥10% and PT_cc + SmT_cc + MedT_cc >60%
Managed young multi-story	MYf	LgT_cc <30% and SS_cc ≥10% and PT_cc + SmT_cc + MedT_cc ≤60% and SmT_cc ≥10% or MedT_cc ≥10%. Has undergone some form of silvicultural treatment, salvage, or roading; contain relatively few large snags and trees (>53.2 cm d.b.h.)
Unmanaged young multi-story	UYf	LgT_cc <30% and SS_cc ≥10% and PT_cc + SmT_cc + MedT_cc ≤60% and SmT_cc ≥10% or MedT_cc ≥10%. Has not undergone active forms of management; contain relatively higher densities of large snags and trees (>53.2 cm d.b.h.)
Old multi-story	Ofm	LgT_cc ≥30% and SS_cc + PT_cc + SmT_cc + MedT_cc >20%
Old single story	Ofs	LgT_cc ≥30% and SS_cc + PT_cc + SmT_cc + MedT_cc ≤20%
Woodland:		
	WDL	All structural stages of the woodland community group were combined as one for this assessment
Stand initiation		PT_cc + SmT_cc + MedT_cc + LgT_cc <10% and SS_cc ≥10%
Stem exclusion		LgT_cc <10% and PT_cc + SmT_cc + MedT_cc ≥10% and SS_cc <10%
Understory reinitiation		LgT_cc <10% and PT_cc + SmT_cc + MedT_cc ≥10% and SS_cc ≥10%
Young multi-story		LgT_cc <10% and SmT_cc + MedT_cc ≥10% and PT_cc ≥10% and SS_cc ≥10%
Old multi-story		LgT_cc ≥10% and SS_cc + PT_cc + SmT_cc + MedT_cc ≥10%
Old single story		LgT_cc ≥10% and SS_cc + PT_cc + SmT_cc + MedT_cc <10%

Table 4—Structural stages defined for assessing the structural features of macrovegetation across the interior Columbia basin, as adapted from Hann and others (1997) (continued)

Structural stage	Structural stage code	Description ^a
Nonforest-nonwoodland: ^b		
Open herbland	Oh	A canopy of herbaceous vegetation with <66% projected canopy cover; <10% cover each of shrubs or trees; ≥1 stratum
Closed herbland	Ch	A canopy of herbaceous vegetation with ≥66% projected canopy cover; <10% cover each of shrubs or trees; ≥1 stratum
Open low-medium shrub	Olms	A canopy of low (<50 cm) or medium-sized (50 cm - 2 m) shrubs with <66% projected canopy cover; shrubs dominate; tree cover <10%; ≥2 strata, ≥2 cohorts possible
Closed low-medium shrub	Clms	A canopy of low (<50 cm) or medium-sized (50 cm - 2 m) shrubs with ≥66% projected canopy cover; shrubs dominate; tree cover <10%; ≥2 strata, ≥2 cohorts possible
Open tall shrub	Ots	A canopy of tall (2 - 5 m) shrubs with <66% projected canopy cover; shrubs dominate; tree cover <10%; ≥2 strata, ≥2 cohorts possible
Closed tall shrub	Cts	A canopy of tall (2 - 5 m) shrubs with ≥66% projected canopy cover; shrubs dominate; tree cover <10%; ≥2 strata, ≥2 cohorts possible
Agricultural		Dominated by crop and pasture land use
Urban		Dominated by rural and urban buildings and facilities
Water		Large bodies of water
Rock		Large areas of rock with <5% vegetative canopy cover

^a Structural stage descriptions include the following abbreviations:

- tree size class: SS = seedlings and saplings [<12.6 cm diameter at breast height (d.b.h.)]; PT = pole trees (12.7 - 22.6 cm d.b.h.); SmT = small trees (22.7 - 40.4 cm d.b.h.); MedT = medium trees (40.5 - 53.1 cm d.b.h.); and LgT = large trees (>53.2 cm d.b.h.).
- cc = crown cover. Crown cover was interpreted in 10-percent increments, and class percentages were expressed as midpoints, for example, 10 percent = 5 to 14 percent, and 20 percent = 15 to 24 percent.

^b Canopy cover related to herblands and shrubs is based on the definition and measurement technique reported in Hann and others (1997; Appendix 3-G, p. 1007) and in Hessburg and others (1999). This technique uses photo interpretation methods at a scale of about 1:12,000, which is not applicable to the fine-scale techniques typically used by Forest Service and BLM field staff on the ground. These agencies typically measure on-the-ground cover at a 1:1 scale, often by a line-intercept technique for shrubs, or by a quadrat microplot for herbaceous plants.

A comparison of the two techniques and scales (1:1 versus 1:12,000) reveals a ratio of about 1:4; i.e., canopy cover thresholds using the photo interpretation (1:12,000) scale will be about 4 times higher than canopy cover thresholds using the line intercept (1:1) scale (S. Bunting, University of Idaho Range Science Department). For example, a 15-percent canopy cover of shrubs using line intercept at a 1:1 on-the-ground scale will be comparable to a 60- to 70-percent canopy cover using photo-interpretation dot-grid techniques at a 1:12,000 scale.

This table uses the definition for canopy cover that is consistent with that used in photo interpretation (i.e., 1:12,000).

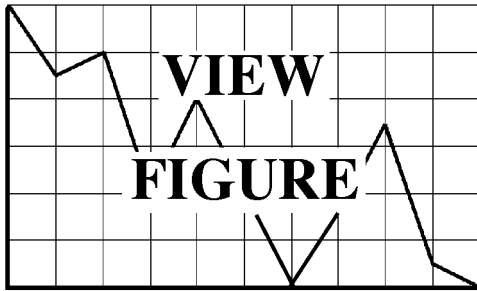


Figure 4—Conceptual framework for the hierarchical system of species, groups, and families as part of a systems ecology approach to identify habitat requirements and habitat trends for 91 broad-scale species of focus within the interior Columbia basin.

within the basin. The resident population was evaluated under the category of resident year-long habitat; this population was identified as occurring primarily in oak woodlands within a narrow band along the western boundary of the basin, immediately south and north of the Columbia River.

We then refined the species-habitat matrices of Marcot and others (1997) by asking experts to identify each cover type-structural stage combination that presumably contributes to positive or stationary population growth for a given species (source habitat) and for a given season of habitat function. We also asked experts to identify nonvegetative factors or fine-scale vegetative characteristics that presumably contribute to stationary or increasing rate of population growth (see special habitat features in vol. 3, appendix 1, table 2). Specifically, the experts (1) identified the seasonal function of source habitat represented in the existing matrix of Marcot and others (1997), (2) converted the existing species-habitat associations to species relations with source habitats, (3) created a separate record of

species-source habitat relations for any additional seasonal habitats needed to fully represent disparate seasons of source habitat function, and (4) refined information as appropriate from the key environmental correlates (Marcot and others 1997) to identify special habitat features.

For a given species, experts assigned a value of one to each combination of cover type-structural stage that was designated as source habitat, and a value of zero to each combination that was designated as nonsource habitat. These same binary codes were used to identify special habitat features deemed to contribute to stationary or positive population growth (value of one) versus those features determined not to contribute to stationary or positive growth (value of zero).

Designations of source habitats and special habitat features for each of the 91 broad-scale species of focus were summarized and stored in two Paradox³ databases (vol. 3, appendix 1, tables 1 and 2). Data in table 1, appendix 1, volume 3, were used as the basis for our analysis of change in source habitats for species and groups. Appendix 2 in volume 3 provides a list of all experts, their professional affiliation, and the associated taxonomic groups of species that each expert addressed in the process described above.

Designing a Hierarchical System of Single- and Multi-Species Assessment

We wanted to develop a system of single- and multi-species assessment that would enable managers to (1) address either single- or multi-species needs, depending on objectives; (2) identify broad-scale, robust patterns of habitat change that affect multiple species in a similar manner; (3) address the needs of many species efficiently, accurately, and holistically with the use of broad-scale strategies and practices; (4) determine how well an evaluation of a group of species or a set of multiple groups of species indexed evaluations conducted for individual species within the groups; and (5) consider dynamics in source habitats at multiple spatial scales and across time to facilitate maximum flexibility in the design and implementation of spatially and temporally explicit strategies.

³ The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

In response to these criteria, we established a hierarchical system to evaluate source habitats for individual species, for groups of species, and for families of groups (fig. 4). Species selected for analysis were clustered into groups based on similarities in source habitats. Likewise, groups of species were placed within families based on similarities in source habitats. Each species within a group, and each group within a family, was nested completely within each higher level grouping (fig. 4). That is, each species was assigned to one group, and each group assigned to one family.

This hierarchical nesting allowed for analysis to be flexible and adaptive. For example, managers often must generalize or blend the habitat requirements of many species to accommodate the composite needs of all species under ecosystem management. Each species, however, occupies its own niche and therefore has a unique set of habitat requirements, thereby suggesting that broad-scale, ecosystem-based management strategies may address the needs of some species better than others (Marcot and others 1994). Under our system, the degree to which a given set of management strategies meets the needs of each species can be quantified by evaluating the efficacy of the management strategies at all three levels: species, group, and family. Often, results of the family or group evaluations likely reflect the species evaluations accurately; in such cases, the higher levels of generalization (group or family) index the species-level phenomenon more efficiently than a species-by-species approach. When the requirements of a given species are not reflected well at the level of the group or family, however, evaluations of individual species can be used to complement the group- or family-level evaluations. For example, a species listed as federally threatened or endangered may have specialized or stringent habitat requirements that dictate specific consideration within a broader, ecosystem-based approach. Under our hierarchical system of species-, group-, and family-level evaluations, managers can choose multiple levels of display regarding habitat trends for species, groups, or families, depending on objectives and the level of generalization desired.

In essence, our system of single- and multi-species assessment represents the combined use of coarse-filter and fine-filter approaches described by Noss (1987) and Hunter (1991). Coarse-filter species management assumes that managing an appropriate amount and

arrangement of all representative land areas and habitats will provide for the needs of all associated species. By contrast, fine-filter species management provides habitats for a single or a few species only. To date, biologists and managers have argued in favor of one approach over another (for example, Hunter 1991), with few or no efforts made to combine coarse- and fine-filter species management in a hierarchical framework (but see Hansen and others [1993] as one attempt to hybridize coarse- and fine-filter approaches). Our hierarchical system of single- and multi-species assessment represents one of the first attempts to combine past, seemingly disparate approaches at evaluating single versus multiple species, and to apply our new method at multiple spatial scales and periods.

In addition to the lack of methods available to managers for conducting multi-species assessment efficiently and accurately, vertebrate ecologists have largely been unsuccessful in developing methods of multi-species assessment that accurately reflect the habitat needs of individual species (Mannan and others 1984), particularly in terms of addressing population persistence (Conroy and Noon 1996). Consequently, we used our assessment of trends in source habitats that were conducted at all three levels—species, group, and family—to evaluate how well the group- and family-level assessments reflected the species-level assessments from an ecological view. We did this by calculating correlation coefficients of habitat trends among species within groups and within families, and comparing those coefficients with coefficients calculated for species among groups and families. (See “Correlating Change in Source Habitats Between Species within Groups and Families” below). Our hierarchical approach therefore is different from past attempts to index the needs of a large set of species by using shortcut methods that typically did not test how well such indices actually represent the needs of the larger, targeted set of species (Marcot and others 1994). Examples of such shortcut methods include the use of coarse filters (Hunter 1991, Noss 1987), management indicator species (Landres and others 1988, Marcot and others 1994), umbrella or flagship species (Landres and others 1988, Marcot and others 1994), species or indicator guilds (Morrison and others 1992, Szaro 1986, Verner 1984), and measures of species diversity such as hotspots, gaps, and centers of endemism (Marcot and others 1997, Scott and others 1993). Intended or empirical applications of these shortcut methods generally do not evaluate the needs

of individual species in relation to the index but instead simply presume that the method correctly indexes the needs of a larger set of species (Hunter 1990, Morrison and others 1992, Noss 1987). Moreover, users of the shortcut methods often fail to reference the larger set of species presumably being indexed (Morrison and others 1992).

Although our hierarchical system may have advantages over previous attempts to index the needs of many species with a few indicators, our system may not perform well under assessments of microhabitats, or for evaluations of fine-scale changes in microhabitats (Mannan and others 1984). For example, two species of birds that each depend on the same old-forest habitat may respond similarly to clearcutting of an old-forest stand; that is, if the stand is eliminated, habitat for both species is removed. Each species, however, may respond differently to the selective removal of large snags, while maintaining the large overstory trees in the stand, if one species depends on large snags and the other does not. Szaro (1986) makes this distinction in his evaluation of guilds as predictive tools and cautions biologists not to simply declare a tool as either flawed or successful without applying and judging the tool at the proper spatial scale. We advise biologists to consider this same context when using our hierarchical system: it was intended for broad-scale, coarse-level evaluations, not as a fine-scale tool to evaluate microhabitats. Consequently, use of higher level groupings of species may not always be appropriate when conducting fine-scale, local evaluations of within-stand or microhabitat changes for multiple species of vertebrates

Clustering the Species into Groups

To begin building our hierarchical system of habitat evaluation for species, groups, and families, we used hierarchical cluster analysis to form 40 groups (table 5) of the 91 broad-scale species of focus. Composite groups were identified by using a hierarchical clustering algorithm based on pairwise similarities in source habitats between species (vol. 3, appendix 1, table 1). For each pair of species, similarity was estimated by using the Ochiai index of similarity (*OI*) (Ludwig and Reynolds 1988):

$$OI_{ij} = \frac{a_{ij}}{\sqrt{a_{ij}+b_i} \sqrt{a_{ij}+c_j}},$$

where a_{ij} is the number of source habitats shared by species i and j , and b_i and c_j are the number of source habitats unique to species i and j , respectively. The *OI* index can range from a minimum value of zero (no shared habitats) to a maximum of one (identical use of habitats). Relative to other similarity measures (Krebs 1989, Romesburg 1984), the *OI* index is more heavily weighted by the number of habitats in common, rather than those habitats not shared by each pair. The complement of similarity, or dissimilarity (D_{ij}), is defined as one minus the similarity.

Dissimilarities between each pair of species were used to generate a distance matrix that was used in the clustering procedure. We used a hierarchical clustering procedure (Proc Clus, SAS Inc. 1989a, p. 519-614) that began with 91 species and then sequentially joined species and groups of species into progressively fewer clusters until all species were joined in a single cluster. We identified various numbers of clusters (Proc Tree, SAS Inc. 1989c, p. 1613-1632) that statistically provided the best fit to the data based on the pseudo t^2 and F -statistics generated by the cluster procedure (Proc Clus, SAS Inc. 1989a, p. 519-614). We then examined species membership within each set of clusters, looking for a degree of aggregation that would be consistent with our ecological understanding of species relations. Based on this examination, we chose the smallest number of groups that allowed aggregation without loss of important, unique patterns in source habitats for particular species. Experts then reviewed our initial groups and made recommendations for refining species membership and the number of groups to bring forward for analysis. We reviewed the experts' recommended changes, made additional refinements, and obtained additional review from experts to arrive at the final list of 40 groups (table 5).

Assessing Change in Source Habitats From Historical to Current Conditions for Species and Groups

Species-level change—We calculated the change in abundance of source habitats from early European to current periods for each of the 91 broad-scale species of focus. Change in source habitats was evaluated by using a combination of species range maps (Marcot and others, in prep.), historical and current broad-scale vegetation maps (Hann and others 1997), and the

Table 5—Membership of 91 broad-scale species of focus in 40 groups and their associated residency and season of habitat function

Class ^a	Group	Common name	Common name code	Season evaluated
B	1	White-headed woodpecker	WHWDPECK	Resident year-long
B	1	White-breasted nuthatch	WBNUTHAT	Resident year-long
B	1	Pygmy nuthatch	PNUTHAT	Resident year-long
B	2	Lewis' woodpecker (migrant population)	LWDPECKMI	Migrant breeding
M	3	Western gray squirrel	WESQUIRR	Resident year-long
B	4	Blue grouse (winter)	BLGRSEWI	Resident winter
B	5	Northern goshawk (summer)	GOSHKSU	Resident summer
B	5	Flammulated owl	FLAMMOWL	Migrant breeding
M	5	American marten	MARTEN	Resident year-long
M	5	Fisher	FISHER	Resident year-long
B	6	Vaux's swift	VSWIFT	Migrant breeding
B	6	Williamson's sapsucker	WSAPSUC	Migrant breeding
B	6	Pileated woodpecker	PWDPECK	Resident year-long
B	6	Hammond's flycatcher	HFLYCAT	Migrant breeding
B	6	Chestnut-backed chickadee	CBCHICKD	Resident year-long
B	6	Brown creeper	BCREEPER	Migrant breeding
B	6	Winter wren	WWREN	Resident summer
B	6	Golden-crowned kinglet	GCKINGLT	Resident summer
B	6	Varied thrush	VTHRUSH	Resident summer
M	6	Silver-haired bat	SILVBAT	Resident summer
M	6	Hoary bat	HOARYBAT	Resident summer
B	7	Boreal owl	BOREOWL	Resident year-long
B	8	Great gray owl	GRGROWL	Resident year-long
B	9	Black-backed woodpecker	BBWDPECK	Resident year-long
B	10	Olive-sided flycatcher	OSFLYCAT	Migrant breeding
B	11	Three-toed woodpecker	TTWDPECK	Resident year-long
B	11	White-winged crossbill	WWCROSSB	Migrant winter
M	12	Woodland caribou	WCARIBOU	Resident year-long
M	13	Northern flying squirrel	NOSQUIR	Resident year-long
B	14	Hermit warbler	HEWARB	Migrant breeding
M	15	Pygmy shrew	PYGSHREW	Resident year-long
M	15	Wolverine	WOLVERIN	Resident year-long
M	16	Lynx	LYNX	Resident year-long
B	17	Blue grouse (summer)	BLGRSESU	Resident summer
B	17	Mountain quail (summer)	MTQUAIL	Resident summer
B	18	Lazuli bunting	LZBNTNG2	Migrant breeding
M	19	Gray wolf	GRAYWOLF	Resident year-long

Table 5—Membership of 91 broad-scale species of focus in 40 groups and their associated residency and season of habitat function (continued)

Class ^a	Group	Common name	Common name code	Season evaluated
M	19	Grizzly bear	GRBEAR	Resident year-long
M	20	Mountain goat	MTGOAT	Resident year-long
B	21	Long-eared owl	LEOWL	Resident year-long
M	22	California bighorn sheep	CBISHEEP	Resident year-long
M	22	Rocky Mountain bighorn sheep (summer)	RBISHEPSU	Resident summer
M	22	Rocky Mountain bighorn sheep (winter)	RBISHEPWI	Resident winter
B	23	Rufous hummingbird	RHUMBIRD	Migrant breeding
B	23	Broad-tailed hummingbird	BTHUMBRD	Migrant breeding
R	24	Sharptail snake	SHSNAKE	Resident year-long
R	24	California mountain kingsnake	CALSNAKE	Resident year-long
B	24	Black-chinned hummingbird	BCHUMBRD	Migrant breeding
B	25	Northern goshawk (winter)	GOSHKWI	Resident winter
M	26	Yuma myotis	YUMYOTIS	Resident year-long ^b
M	26	Long-eared myotis	LEMYOTIS	Resident year-long ^b
M	26	Fringed myotis	FRMYOTIS	Resident year-long ^b
M	26	Long-legged myotis	LLMYOTIS	Resident year-long
B	27	Pine siskin	PSISKIN	Migrant breeding
M	27	Townsend's big-eared bat	PALEBAT	Resident year-long
M	28	Western small-footed myotis	WEMYOTIS	Resident year-long
M	28	Spotted bat	SPOBAT	Resident year-long ^b
M	28	Pallid bat	PALLBAT	Resident year-long ^b
B	29	Western bluebird	WBLUEBRD	Migrant breeding
B	30	Ash-throated flycatcher	ATFLYCAT	Migrant breeding
B	30	Bushtit	BSHTIT	Resident year-long
B	31	Ferruginous hawk	FERRHWK	Migrant breeding
B	31	Burrowing owl	BURROWL	Migrant breeding
B	31	Short-eared owl	SEOWL	Resident year-long
B	31	Vesper sparrow	VESPARRO	Migrant breeding
B	31	Lark sparrow	LASPARRO	Migrant breeding
B	31	Western meadowlark	WMEDLRK	Migrant breeding
M	31	Pronghorn	PRONGHOR	Resident year-long
R	32	Mojave black-collared lizard	MOLIZARD	Resident year-long
R	32	Longnose leopard lizard	LOLIZARD	Resident year-long
R	32	Striped whipsnake	STWSNAKE	Resident year-long
R	32	Longnose snake	LONSNAKE	Resident year-long
R	32	Ground snake	GROSNAKE	Resident year-long
M	32	Preble's shrew	PRESHREW	Resident year-long

Table 5—Membership of 91 broad-scale species of focus in 40 groups and their associated residency and season of habitat function (continued)

Class ^a	Group	Common name	Common name code	Season evaluated
M	32	White-tailed antelope squirrel	WHSQUIR	Resident year-long
M	32	Washington ground squirrel	WGRSQUIR	Resident year-long
M	32	Wyoming ground squirrel	WYGRSQUI	Resident year-long
M	32	Uinta ground squirrel	UGRSQUIR	Resident year-long
B	33	Sage grouse (summer)	SGRSESU	Resident summer
B	33	Sage grouse (winter)	SGRSEWI	Resident winter
B	33	Sage thrasher	STHRASH	Migrant breeding
B	33	Brewer's sparrow	BRSPARRO	Migrant breeding
B	33	Sage sparrow	SASPARRO	Migrant breeding
B	33	Lark bunting	LRKBUNT	Migrant breeding
M	33	Pygmy rabbit	PYRABBIT	Resident year-long
M	33	Sagebrush vole	SAGEVOLE	Resident year-long
B	34	Black-throated sparrow	BTSPARRO	Migrant breeding
M	34	Kit fox	KITFOX	Resident year-long
B	35	Loggerhead shrike	LSHRIKE	Migrant breeding
B	36	Columbian sharp-tailed grouse (summer)	STGRSESU	Resident summer
B	37	Clay-colored sparrow	CCSPARRO	Migrant breeding
B	37	Grasshopper sparrow	GRSPARRO	Migrant breeding
M	37	Idaho ground squirrel	IDGRSQUI	Resident year-long
B	38	Black rosy finch	BRFINCH	Resident summer
B	38	Gray-crowned rosy finch	GCRFINCH	Resident summer
B	39	Lewis' woodpecker (resident population)	LWDPCKRE	Resident year-long
B	40	Brown-headed cowbird	BHCOWBRD	Migrant breeding

^a B = bird, M = mammal, and R = reptile.

^b It is not known whether these bat species hibernate within the basin or leave the basin during winter. In the absence of migratory information, we have assumed that source habitats for these species include winter hibernacula, in addition to nonwinter habitat.

species-source habitats information that we generated. The change in available source habitats from early European settlement to the present was estimated in a six-step process:

1. The inclusive area over which a species occurs currently was estimated by using range maps developed by Marcot and others (in prep.), as described earlier. If the current range of a species had contracted significantly from its historical range, we used its historical range (Marcot and others, in prep.). Range maps were digitized and

translated into a grid map composed of 1-km² (0.4-mi²) pixels, consistent with the vegetation grids prepared by Hann and others (1997).

2. Overlaying the species range grid maps and the current and historical vegetation grid maps (from Hann and others 1997), we then used the species-source habitats information (vol. 3, appendix 1, table 1) to identify individual pixels within the range of a species that were designated as source habitats, historically and currently.

3. For a given species and subwatershed, the percentage of area deemed to be source habitat was calculated as the number of pixels designated as source habitats divided by the total number of pixels in the subwatershed, multiplied by 100. For areas larger than a subwatershed (basin, ERU, subbasin, or watershed), the percentage of area (also referred to as aerial extent, abundance, or extent) deemed to be source habitat historically (H_S) or currently (C_S) for a species was calculated as the number of pixels in source habitat divided by the total number of pixels in the specified area, multiplied by 100, but excluding those subwatersheds that both historically and currently contained no pixels of source habitat.

It is important to note that at least one pixel of source habitat had to be present, either historically or currently, for a subwatershed to be included in our estimate of H_S and C_S at scales of the watershed, subbasin, ERU, or basin. For example, if one of three subwatersheds composing a watershed contained no pixels of source habitat, both historically and currently, this subwatershed was excluded from the calculation of percentage of area for both H_S and C_S for the species in the watershed. Exclusion of subwatersheds that contained no source habitats ensured that large areas of nonhabitat would not dilute the calculation of habitat change that was estimated to occur from historical to current periods for each species at scales larger than a subwatershed. In essence, this exclusion of subwatershed-sized areas of nonhabitat from our calculations is a fine-scale correction for situations where the range of a species was erroneously mapped to include such areas of nonhabitat, particularly along peripheries of a range map.

4. The absolute change in percentage of area of source habitats from historical to current periods, for a given species for a specified area larger than a subwatershed (ACH_S), was calculated as $ACH_S = C_S - H_S$.
5. The relative change in percentage of area of source habitats from historical to current periods, for a given species in a specified area larger than a subwatershed (RCH_S), was calculated as $RCH_S = [(C_S - H_S) / (H_S)] \times 100$.

6. The values of RCH_S for each species were converted to ordinal measures of relative change in percentage of area of source habitats, referred to as trend categories (TC_S). Five trend categories were established: 2, 1, 0, -1, and -2, where 2 equals “strongly increasing,” corresponding to values of RCH_S greater than or equal to a 60-percent increase; 1 equals “increasing,” corresponding to values of RCH_S greater than or equal to a 20-percent but less than a 60-percent increase; 0 equals “no change,” corresponding to positive or negative values of RCH_S less than 20 percent; -1 equals “decreasing,” corresponding to values of RCH_S greater than or equal to a 20-percent but less than a 60-percent decline; and -2 equals “strongly decreasing,” corresponding to values of RCH_S greater than or equal to a 60-percent decline.

Values of TC_S for each species were calculated for the entire basin and for each ERU within the basin, considering all land ownership (both public and private lands). Results were displayed by species, with TC_S values ordered for each species from most negative to most positive changes at the basin and the ERU scales. Because some watersheds occurred in more than one ERU, we partitioned these watersheds among the appropriate ERUs. This resulted in 23 additional watershed/ERU combinations for our calculations of TC_S .

Change in source habitats at the scale of the basin also was analyzed for public and mixed-ownership lands only; this was done by excluding all subwatersheds from the analysis that were composed entirely of private lands. This analysis allowed us to contrast the amount of relative change, or RCH_S , that was attributed to public and mixed-ownership lands versus all lands for each species. This partitioning of the contribution of public and mixed-ownership lands, exclusive of private lands, to a change in source habitats is important to managers, who need insight about differences in habitat change on public-dominated ownership versus all lands.

Group-level change—We calculated change in source habitats for each of the 40 groups using the same general steps used for individual species, but with one important difference. At the 1-km² (0.4-mi²) pixel level, the percentage of area deemed to be

source habitats for the group historically (H_G) or currently (C_G), or “group score” historically or currently (G_S), was calculated as:

$$G_S = \frac{\sum_{i=1}^k s_i}{\sum_{i=1}^k r_i},$$

Where s_i indicates source habitats present, either historically or currently, for species i within the range of species i , r_i indicates whether the pixel is within the range of species i , and k is the number of species within the group. Both s_i and r_i are binary (0,1) variables; group scores range in value from zero to one. Calculated in this manner, group scores at the pixel level depend only on the species whose ranges include a given pixel. Thus for a group composed of 10 species, a pixel that contains source habitat for a single member species and is within the range of only that species would have the same score as a pixel within the range of all 10 species that supports all 10. For a specified area of the basin, group scores were calculated simply as the mean of the pixel-level scores over all pixels within the specified area. As was done with the species calculations, only those subwatersheds containing at least one pixel of source habitat, either historically or currently, were included in the calculations of group scores. Group-level measures of absolute change (ACH_G), relative change (RCH_G), and trend categories of change (TC_G) from historical to current were calculated in the same manner as done for species-level changes.

The translation of the numeric measure of relative change (RCH_S) to the ordinal trend categories (TC_S) for both species and groups was intended to provide a consistent means of displaying relative change among species and groups at various scales of the basin. It should not be interpreted as a measure of statistical significance. Unfortunately, the method used to estimate change in source habitats does not lend itself to precise estimates of error. The accuracy of any given estimate depends on the combination of how well we have characterized the species range, the historical and current distribution of vegetation, and the associations between species and vegetation. Analysis of the

vegetation maps suggests that the accuracy of compositional predictions increases as the scale of aggregation increases (Hann and others 1997); that is, the estimated composition of the landscape at the ERU and larger scales is likely to be more accurate than individual summaries at smaller scales, as described earlier in our methods under “Estimating and Validating Occurrence of Cover Types and Structural Stages for Broad-Scale Assessment.”

Increased accuracy of vegetation estimates at ERU and basin scales versus smaller scales implies that our estimates of change in source habitats for individual species and groups are more likely to be accurate at larger scales as well. We also expect the accuracy of our predictions to be species-dependent. In general, estimates for species with broad ranges that use many source habitats are likely to be more accurate than estimates for narrowly distributed species that use few source habitats.

Forming Families of Groups to Summarize Results Among Multiple Groups

Families of groups—To complete our hierarchical system of evaluating species, groups, and families, we further generalized our group-level results by placing 37 of the 40 groups into 12 families (fig. 5, table 6). Families were defined by using the generalized vegetative themes shown in figure 5, based on a combination of formal cluster analysis (Proc Clus, SAS Inc. 1989a, p. 519-614) and empirical knowledge of the habitat requirements of each species. The clustering method used to guide placement of groups into families was identical to that used to join species into groups (see methods, “Clustering the Species into Groups”), with one exception: instead of clustering species based on similarities in cover-type structural stage combinations that explicitly define source habitats, clustering was done on similarities of species in the 24 terrestrial community types developed by Hann and others (1997).

The 24 terrestrial community types are a higher level generalization of the cover types and structural stages and provide a hierarchy within which all cover type-structural stage combinations are nested. (See Hann and others (1997) for a detailed description of the hierarchical system of nesting cover type-structural

Table 6—Membership of 37 groups and 88 broad-scale species of focus in 12 families

Family	Group	Common name	Terrestrial family name
1	1	White-headed woodpecker	Low-elevation old forest
1	1	White-breasted nuthatch	
1	1	Pygmy nuthatch	
1	2	Lewis' woodpecker (migrant population)	
1	3	Western gray squirrel	
2	4	Blue grouse (winter)	Broad-elevation old forest
2	5	Northern goshawk (summer)	
2	5	Flammulated owl	
2	5	American marten	
2	5	Fisher	
2	6	Vaux's swift	
2	6	Williamson's sapsucker	
2	6	Pileated woodpecker	
2	6	Hammond's flycatcher	
2	6	Chestnut-backed chickadee	
2	6	Brown creeper	
2	6	Winter wren	
2	6	Golden-crowned kinglet	
2	6	Varied thrush	
2	6	Silver-haired bat	
2	6	Hoary bat	
2	7	Boreal owl	
2	8	Great gray owl	
2	9	Black-backed woodpecker	
2	10	Olive-sided flycatcher	
2	11	Three-toed woodpecker	
2	11	White-winged crossbill	
2	12	Woodland caribou	
2	13	Northern flying squirrel	
3	14	Hermit warbler	Forest mosaic
3	15	Pygmy shrew	
3	15	Wolverine	
3	16	Lynx	
3	17	Blue grouse (summer)	
3	17	Mountain quail (summer)	
4	18	Lazuli bunting	Early-seral montane and lower montane
5	19	Gray wolf	Forest and range mosaic
5	19	Grizzly bear	
5	20	Mountain goat	
5	21	Long-eared owl	
5	22	California bighorn sheep	
5	22	Rocky Mountain bighorn sheep (summer)	
5	22	Rocky Mountain bighorn sheep (winter)	
6	23	Rufous hummingbird	Forests, woodlands, and montane shrubs
6	23	Broad-tailed hummingbird	
6	24	Sharptail snake	
6	24	California mountain kingsnake	

Table 6—Membership of 37 groups and 88 broad-scale species of focus in 12 families (continued)

Family	Group	Common name	Terrestrial family name
6	24	Black-chinned hummingbird	Forests, woodlands, and sagebrush
6	25	Northern goshawk (winter)	
7	26	Yuma myotis	
7	26	Long-eared myotis	
7	26	Fringed myotis	
7	26	Long-legged myotis	
7	27	Pine siskin	
7	27	Townsend's big-eared bat	
7	28	Western small-footed myotis	
7	28	Spotted bat	
7	28	Pallid bat	
8	29	Western bluebird	Rangeland and early- and late-seral forest
9	30	Ash-throated flycatcher	Woodland
9	30	Bushtit	
10	31	Ferruginous hawk	Range mosaic
10	31	Burrowing owl	
10	31	Short-eared owl	
10	31	Vesper sparrow	
10	31	Lark sparrow	
10	31	Western meadowlark	
10	31	Pronghorn	
10	32	Mojave black-collared lizard	
10	32	Longnose leopard lizard	
10	32	Striped whipsnake	
10	32	Longnose snake	
10	32	Ground snake	
10	32	Preble's shrew	
10	32	White-tailed antelope squirrel	
10	32	Washington ground squirrel	
10	32	Wyoming ground squirrel	
10	32	Uinta ground squirrel	
11	33	Sage grouse (summer)	Sagebrush
11	33	Sage grouse (winter)	
11	33	Sage thrasher	
11	33	Brewer's sparrow	
11	33	Sage sparrow	
11	33	Lark bunting	
11	33	Pygmy rabbit	
11	33	Sagebrush vole	
11	34	Black-throated sparrow	
11	34	Kit fox	
11	35	Loggerhead shrike	
12	36	Columbian sharp-tailed grouse (summer)	Grassland and open-canopy sagebrush
12	37	Clay-colored sparrow	
12	37	Grasshopper sparrow	
12	37	Idaho ground squirrel	

habitats are restricted to forests composed of early-seral stages. Additional contrast is illustrated by families five through eight; these families consist of groups whose source habitats include both forest and rangeland environments. Moreover, families 9 through 12 consist of groups whose source habitats include only rangeland-woodland environments.

Note that two groups (group 38, composed of two species of rosy finches, and group 39, composed of the resident Lewis' woodpecker) were not placed in any of the families because their source habitats were restricted to small areas of the basin and were potentially under-sampled because of the finer scale pattern at which their habitats exist. Moreover, group 40, which consists of one species, the brown-headed cowbird, also was excluded from the families because of its unique dependence on agricultural and livestock-dominated environments, and because change in its source habitats was already analyzed and shown clearly in the analysis at the group level.

Evaluating change in source habitats by family—

For each of the 12 families, we summarized the change in percentage of area of source habitats from historical to current periods for each ERU using the following process. First, each watershed was assigned to one of three change classes: positive, negative, or neutral. Change classes were based on summary statistics calculated from the five trend categories of relative change for each group (TC_G) in the family. For a given family, a watershed was classified as positive if >50 percent of the groups in the watershed increased in source habitats by 20 percent or more (TC_G of 1 or 2). A watershed was classified as negative if >50 percent of the groups in the watershed declined in source habitats by 20 percent or more (TC_G of -1 or -2). Watersheds not classified positive or negative were classified as neutral. Estimates of the dominant trend in source habitats were then derived for each family for each of the 13 ERUs by (1) calculating the percentage of watersheds that were increasing, decreasing, or neutral for each family in each ERU; (2) classifying the ERU as increasing or decreasing if >50 percent of the watersheds had positive or negative trends, respectively; and (3) classifying the ERU as neutral if not classified as either increasing or decreasing.

Correlating Change in Source Habitats Between Species Within Groups and Families

Clustering of species into groups and families could result in contradictory changes in source habitats among species within a group or family. This is possible because every species except two—the black rosy finch and the gray-crowned rosy finch—is associated with a unique set of source habitats; that is, the set of source habitats for each species is different from all other species (vol. 3, appendix 1, table 1). Thus, for a given analysis area, particular source habitats that are unique to one species in a group or family could change markedly and in a different direction than another set of source habitats that are unique to one or more other species in the same group or family.

To determine if this problem existed, we calculated a nonparametric correlation coefficient, Kendalls' Tau (r_k) (Proc Corr, SAS Inc. 1989b, p. 209-235) of the relative change (RCH_S) in source habitats between each pair of species within each group and family (within-group or within-family coefficients), and among all species pairings between groups and families (between-group or between-family coefficients). Correlation coefficients were calculated on changes in source habitats that were measured at the scale of the watershed, by using all watersheds under joint occupation of each species pair. A positive coefficient (r_k values >0 and ≤ 1) for a given pair of species indicated positive agreement in direction of change in source habitats across watersheds for the pair. Values near one indicated strong positive agreement, whereas values near but above zero indicated weak positive agreement. Zero or negative coefficients (r_k values of 0 or ≤ -1) indicated no relation or contradictory trends in source habitats between a species pair.

We interpreted positive correlation coefficients among all species pairings within a group or family as verification that the direction of change in source habitats calculated for the group or family reflected a like direction of change for all species within the group or family. Zero or negative coefficients between pairs of species within a group or family indicated that calculations of group- or family-level change might be suspect because of contradictory trends in source habitats among one or more species pairings. In the latter case,

our intention was to redefine group or family membership to alleviate contradictory trends among one or more species.

To further interpret the efficacy of a group or family trend as an index of species trends within the group or family, we compared the within-group or within-family coefficients for each group or family with the mean correlation coefficient calculated for all between-group and between-family coefficients. Presumably, correlation coefficients of trend for within-group or within-family species pairings should be higher than correlation coefficients calculated for species pairings between groups or between families. If the opposite was observed, it suggested that species membership within certain groups or families could be changed to achieve a higher level of agreement in habitat trends between two or more species.

Summarizing Knowledge About Species-Road Relations

Many species of vertebrates are negatively affected by roads and the human activities associated with roads (for example, see Bailey and others 1986, Bashore and others 1985, Cole and others 1997, Fraser 1979, Hodgman and others 1994, Mattson and others 1996b, Mech and others 1988, Scott and Servheen 1985, Singer 1978, Thiel 1985). Moreover, human presence and activities are facilitated by increased access provided by roads (Hann and others 1997). Consequently, we summarized knowledge about species-road relations for each of the 91 broad-scale species of focus using the following steps. First, we conducted a literature search, and from that, identified 13 factors that consistently are associated with the negative impact of roads on populations or habitats of terrestrial vertebrates. We then characterized the potential effects of each factor on each species of focus in one of four ways: (1) a documented effect of the factor, with explicit association of roads as a facilitator of the effect, that was demonstrated in one or more studies on the species; (2) a documented effect of the factor, but without explicit association of roads as a facilitator of the effect, that was demonstrated in one or more studies on the species; and (3) a presumed effect of the factor, based on documented effects of the factor and of roads as a facilitator of the effect, that was demonstrated in one or more studies on species of similar life history or taxa; (4) a presumed effect of

the factor, based on documented effects of the factor and of roads as a facilitator of the effect, in causing declines in habitat condition on which the species depends.

To provide spatial context for road-associated effects on terrestrial vertebrates, we portrayed the broad-scale pattern of road density across the basin using a pixel-based prediction of six classes of road density that was derived originally by Menakis and others (1996) and discussed in Hann and others (1997). We then identified and discussed potential management actions that could mitigate some or all of the negative effects associated with the spatial pattern of road density. The six classes of road density predicted by Menakis and others (1996) are (1) zero (0 to 0.02 mi of road per mi²) (0 to 0.01 km per km²); very low (>0.02 to 0.1 mi per mi²) (0.01 to 0.06 km per km²); low (>0.1 to 0.7 mi per mi²) (>0.06 to 0.44 km per km²); moderate (>0.7 to 1.7 mi per mi²) (>0.44 to 1.06 km per km²); high (>1.7 to 4.7 mi per mi²) (>1.06 to 2.94 km per km²); and very high (>4.7 mi per mi²) (>2.94 km per km²). Methods used to predict these spatially explicit road classes are described in the following section.

Characterizing road density—A data set composed of continuous, mapped coverage of roads was not available for the basin. Consequently, a geographical information system (GIS) layer of predicted road density was developed at 1-km² (0.4-mi²) resolution with a statistical rule set (Menakis and others 1996). This layer was summarized to the subwatershed level by using an average based on the six classes of road density identified above. The rule set for extrapolation of road density classes to create the broad-scale road density map was developed from a statistical correlation calculated between road density estimated from a sample of 1-km² (0.4-mi²) cells and estimates of other variables that were available in continuous coverage of all 1-km² (0.4-mi²) cells across the basin. The data set for sampled road density came from roads sampled as part of the mid-scale landscape characterization (Gravenmier and others 1997, Hessburg and others 1999, Ottmar and others 1996) and valley bottom characterization (Gravenmier and others 1997, Jensen and others 1997). Menakis and others (1996), Gravenmier and others (1997), and Hann and others (1997) described additional details about methods used to predict the classes of road density at the broad scale and limitations on use of the data.

Mapping Road Density in Relation to Abundance of Source Habitats for Selected Species

Roads hypothetically pose a direct threat to population fitness for several terrestrial carnivores by facilitating overtrapping (wolverine and lynx) or other fatal interactions with humans (gray wolf and grizzly bear). For gray wolf and grizzly bear, researchers have verified a strong, negative relation between road density and population fitness (Mace and others 1996, Mattson and others 1996b, Mech and others 1988, Thiel 1985). Similar relations have been hypothesized for wolverine and lynx within the basin (ICBEMP 1996b, 1996c), and limited research on lynx (Bailey and others 1986) outside the basin supports the hypothesis that population fitness is lower in areas characterized by increased road access (but see Ruggiero and others [1999] regarding alternative hypotheses). Because of these observed or suspected effects on population fitness, we mapped the current abundance (percentage of area or C_S , as defined earlier) of source habitats in relation to road density for each of the four species mentioned above. Mapping was intended to identify large areas of abundant source habitats that have low road density. Presumably, these areas would have highest potential to support populations that could persist without additive mortality that may be caused by road-associated factors.

Mapping involved three steps: (1) generating a map of current habitat abundance for each species at the appropriate scale; (2) generating a map of road density at the same scale as the map of habitat abundance; and (3) generating a map of the intersection of moderate to high habitat abundance with zero to low road density. Each of these maps was generated at the subbasin scale. Subbasins were used as mapping units because their large size (mean size of 345 000 ha [850,000 acres] each) is compatible with the broad scale at which lynx, wolf, wolverine, and grizzly bear function to meet their life requirements.

Generating the map of current habitat abundance for each species involved two steps. First, we calculated the current percentage of area (C_S) in each subbasin that was composed of source habitats. And second, we classified and mapped each subbasin as belonging to one of three classes—high, moderate, or low—with the highest one-third of values classified as high abundance, the middle one-third as moderate abundance,

and the lowest one-third of values as lowest abundance. Maps of current abundance of source habitats were generated over the entire area estimated to be within the historical range of each species within the basin. Abundance of source habitats was mapped within historical ranges because we wanted to identify all areas of the basin that might be characterized as having moderate to high abundance of source habitats and zero to low density of roads within potential use areas for each species.

Generating the map of road density by subbasin involved four steps. First, we calculated the percentage of area in each watershed within each subbasin that had (1) zero to low road density (≤ 0.7 mi of roads per mi^2); (2) moderate road density (0.7 to 1.7 mi of roads per mi^2); (3) high to very high road density (> 1.7 mi of roads per mi^2). Second, we used these percentages to identify which of these three composite classes of road density—zero to low, moderate, or high to very high—dominated the watershed. If > 50 percent of the area of the watershed was composed of one of the three composite classes of road density, that class was identified as dominant. In cases where none of the three classes made up > 50 percent of the watershed, the moderate class of road density was identified as dominant. Third, we calculated the percentage of watersheds within the subbasin that had a dominant road class of zero to low, moderate, and high to very high. And fourth, we classified the subbasin as being dominated by zero to low or high to very high road density if > 50 percent of the watersheds within the subbasin were dominated by these classes.

To generate the map of the intersection of habitat abundance with zero to low road density for each species by subbasin, we overlaid and then outlined the subbasins dominated by zero to low road density onto the map of habitat abundance for each species. These integrated maps were displayed for each species of terrestrial carnivore and results discussed in terms of current knowledge of the effects of roads on the habitats and populations of the species.

Interpreting Results and Describing Management Implications

Species-level interpretation and implications—

Our purpose for assessment was to adopt a “systems approach” for evaluating change in source habitats for

an inclusive list of terrestrial vertebrates whose habitats were suspected to have declined. We therefore focused our management implications on groups of species, and families of groups, rather than individual species. Laws such as ESA and NFMA, however, dictate that species-level needs be attended to and accounted for, regardless of the inherent problems in doing so (Hunter 1990, 1991). Moreover, if species are to be evaluated as groups, the loss of species-level accuracy must be evaluated and accounted for in making appropriate inferences for management.

For these reasons, we analyzed change in source habitats at the species level and addressed the associated management implications. Our implications focused on two subject areas: (1) identifying unique, species-level habitat requirements and habitat conditions that may be obscured by analyzing species as groups; and (2) identifying those species whose habitats have potentially declined so substantially that special management attention may be warranted.

Group-level interpretations and implications—

Ecosystem management demands that robust patterns that potentially exist among multiple species be detected and accounted for, and that broad generalizations about groups of species be made without significant loss of species-level information. Accordingly, we focused our analysis, and subsequent interpretations and implications of the results, on groups rather than species. Interpretations of results at the group level were designed to (1) identify the underlying changes in cover types and structural stages that contributed to any changes observed in source habitats; (2) consider the potential effects of special habitat features not measured in our analysis, such as trends in snag densities or changes in other finer scale or nonvegetative characteristics, that may act in tandem with or independent of group-level changes in source habitats; and (3) consider the potential effects of nonvegetative factors not measured in our analysis that also may act in tandem with or independent of changes in source habitats to influence population status and trend for the broad-scale species of focus.

We did not attempt to discern the potential relation between group-level changes in source habitats and empirical trends in populations of the species within the groups. Evaluation of the change in source habitats for a group in relation to the empirical trends in populations of those species is problematic for at least four reasons. First, the spatial scale at which changes

in source habitats were measured (collections of watersheds within each ERU) was not the same as that at which population data were collected. For example, population trend data often are collected by state agencies, and state boundaries do not coincide with watershed or ERU boundaries. Second, the temporal scale at which changes in source habitats are measured is far longer (>100 yr) than even the longest term data on population trends. For example, Breeding Bird Surveys (BBS) date as far back as the early 1960s, yet most or all of the large-scale changes in source habitats, such as conversion of rangelands to agriculture, may have occurred before then. Third, populations of some species may respond strongly to nonvegetative factors, such as human presence or human activities, which are not accounted for in source habitat trends. For example, the grizzly bear apparently survives well in various habitats that are characterized by little or no human disturbance but survives less well in the same habitats where human presence is high (Mattson and others 1996a, 1996b). And fourth, population trends of many species are difficult to detect without intensive monitoring, which typically has not occurred for most nongame species. Sauer and others (1996b) discuss some of these and additional problems related to analyzing and interpreting BBS data in relation to causal factors such as habitat change.

Because of these limitations, our primary basis for describing management implications focused on interpretation of changes observed in source habitats, combined with summaries of empirical literature available on conditions of special habitat features for each group. Population data that indicated widespread, negative trends or other problems with population status, however, also were considered as part of our description of management implications, regardless of how well such population data agreed with habitat trends. And, whenever possible, we attempted to identify other factors or reasons for apparent disparities between population and source habitat trends when logical or empirical explanations were evident. Accordingly, the management implications described for each group were designed to (1) identify habitat and population issues of most interest to Federal land managers in the basin; (2) list broad-scale management strategies that would be effective in addressing the issues; and (3) outline a comprehensive set of practices that would most effectively support implementation of the strategies.

When reporting population trends, we reported as much statistical detail about the trends, and the magnitude of change, as reported by the source literature. For trends obtained from results of BBS (Sauer and others 1996a), we reported the magnitude of change (percentage of change), the statistical probability of detecting a larger difference than that observed, and the sample size. We also reported BBS summaries of trends for the basin and for each of three major physiographic regions that overlap major segments of the basin (Saab and Rich 1997, Sauer and others 1996a).

Family-level interpretations and implications—

Our purpose for placing groups of species into families was to further generalize the patterns of change in source habitats across subbasins and ERUs in as concise a format as possible without loss of detail. Moreover, we wanted to maintain explicit connections of families to groups, and groups to species, in making such generalizations. In this way, the more detailed group- and species-level results could be related directly and efficiently to family-level generalizations, thereby allowing managers to design and apply conservation strategies and practices at any or all of the three levels of resolution (species, groups, or families).

Thus, we drew implications about family-level results in terms of broad-scale themes of habitat change that supported species- and group-level trends. Themes described major, broad-scale changes in source habitats along major vegetative gradients that may be useful to managers, and on which strategic conservation designs can be based. Specifically, we interpreted and drew implications about family-level results to answer the following questions:

1. What source habitats have undergone the greatest decline from historical to current conditions, and which groups were associated with such declines?
2. What areas of the basin have undergone the greatest decline in source habitats, and what are the spatially explicit causes for decline?
3. What broad-scale management strategies and practices and associated ecological processes would bring about the greatest short- and long-term benefits to conservation or restoration of source habitats that have undergone long-term decline, and which species and groups of species would benefit from which strategies, practices, and ecological processes?

Answering these questions provides spatially explicit management insight about habitat status for collections of groups of species. Moreover, the answers presumably will help managers focus on broad-scale management strategies and practices that most benefit groups of species whose source habitats have undergone the greatest decline.

Validating Agreement Between Change in Source Habitats and Expert-Opinion Based Habitat Outcomes

We assume that the direction of change in source habitats reflects a like direction of trend in the associated population size of the broad-scale species of focus. Note that this is different from assuming that the magnitude of change in source habitats reflects a like magnitude of change in population size, because many factors beyond habitat can influence population trends. For all species analyzed here, however, except those for which concern is based solely on effects of nonvegetative factors such as roads, the assumption that a decline or increase in source habitats contributes to a like direction of change in population size is fundamental to development of credible management strategies and practices. If this assumption is incorrect, then management applications of our results could be misleading. This assumption can be addressed through validation research. We assume that the FS and BLM will fund broad-scale, long-term research to address the relation between our results on habitat trends and empirical estimates of population status and trend for each species analyzed in our paper.

Although broad-scale data on population status and trend have either not been synthesized or not collected at temporal and spatial scales compatible with our analysis, one set of data exists by which to assess agreement between presumed changes in habitat and populations with changes that we estimated for source habitats. Lehmkuhl and others (1997) provided expert-opinion based estimates of historical to current change in habitat amount and distribution (habitat outcomes) for 173 species of terrestrial vertebrates on FS- and BLM-administered lands within the basin. They also provided expert-opinion based estimates of historical to current change in habitat outcomes and presumed population effects based on the cumulative effects of habitat change and nonhabitat factors on all lands

within the basin (cumulative effects outcomes). Estimates of change in habitat and cumulative effects outcomes were generated from a series of expert panels convened in spring 1996. Sixty-eight of these 173 species are on our list of broad-scale species of focus.

For each of these species, we characterized the change in habitat outcomes and in cumulative effects outcomes from historical to current periods from Lehmkuhl and others (1997) as being either positive or negative, and did the same for the change in source habitats at the basin scale. We then calculated the percentage of species whose change in source habitats agreed or disagreed with trends in the habitat outcomes, and with trends in the cumulative effects outcomes. Habitat and cumulative effects outcomes were estimated specifically for each of the two EIS areas (Eastside and Upper Columbia River; USDA Forest Service and USDI Bureau of Land Management 1997a, 1997b). Consequently, we calculated percentage of agreement among trends in source habitats and outcomes for both EIS areas and for a mean trend in outcomes that we calculated by pooling results from both EIS areas.

Species-Level Results and Discussion

Habitat Change by Basin and Ecological Reporting Unit

Basin-wide change—Source habitats for most species—55 of 97 species seasonal entries or 57 percent—declined strongly or very strongly from historical to current periods, based on trend categories of relative change (TC_S) at the basin scale (rank of -1 or -2, table 7). By contrast, few species (6 percent) were associated with source habitats that increased strongly or very strongly (rank of 1 or 2), but a moderate number—36 of 97 species seasonal entries or 37 percent—were associated with source habitats that showed little change (rank of 0).

In contrast to the trends based on categories of relative change, trends in source habitats were consistently more negative when expressed as continuous variables of absolute and relative change (ACH_S and RCH_S).

By using these measures, 80 percent of the species were associated with a change in source habitats that was negative (table 7). Only two species (2 percent) showed no change in source habitats, and 18 percent were associated with change that was positive.

Species whose source habitats declined were associated with many forested and rangeland environments. For example, of the 20 species that underwent the strongest relative decline in source habitats (table 7), 12 are primarily dependent on forested habitats, 7 are largely dependent on rangeland habitats, and 1 is dependent on a combination of forested and rangeland habitats (vol. 3, appendix 1, table 1). This finding indicates that many source habitats have declined in the basin; in turn, this suggests that no particular species or habitats, or small set of species or habitats, are easily identified as needing priority management.

Habitat change by ecological reporting unit—

Species whose source habitats declined strongly or very strongly at the basin scale (trend categories of relative change of -1 or -2, table 7) also experienced strong declines in source habitats within most ERUs (table 8; vol. 3, appendix 1, table 5). For example, the migrant population of Lewis' woodpecker, which showed the greatest relative decline in source habitats among all species at the basin scale (-83 percent, table 7), also had categories of relative change that were -1 or -2 for 100 percent of the ERUs in which the species occurred (table 8). Similarly, the grasshopper sparrow, which had the third greatest relative decline among all species in the basin (-71 percent, table 7), had categories of relative change that were -1 or -2 for 91 percent of the ERUs in which the species occurred (table 8). Other species whose source habitats underwent strong relative decline at the basin level and across most or all ERUs included the Washington ground squirrel, Columbian sharp-tailed grouse, Rocky Mountain bighorn sheep, pygmy nuthatch, flammulated owl, Williamson's sapsucker, western bluebird, white-headed woodpecker, and brown creeper. Source habitats for these species declined by more than 40 percent at the basin scale (table 7), and categories of relative change were either -1 or -2 in more than 75 percent of the ERUs in which these species occurred (table 8).

Table 7—Historical (H_S) and current (C_S) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_S), relative change (RCH_S), and trend categories (TC_S) of relative change^{a b}

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^c
-----Percentage-----							
1	2	Lewis' woodpecker (migrant population)	13.78	2.29	-11.49	-83.35	-2
12	37	Idaho ground squirrel	11.32	3.04	-8.28	-73.13	-2
12	37	Grasshopper sparrow	21.27	6.18	-15.09	-70.94	-2
10	32	Washington ground squirrel	71.66	22.38	-49.28	-68.77	-2
1	1	Pygmy nuthatch	20.42	6.59	-13.83	-67.73	-2
12	37	Clay-colored sparrow	18.60	6.39	-12.21	-65.65	-2
1	1	White-headed woodpecker	22.87	8.50	-14.37	-62.83	-2
2	7	Boreal owl	14.97	5.78	-9.20	-61.42	-2
2	6	Williamson's sapsucker	20.97	9.14	-11.83	-56.42	-1
2	5	Flammulated owl	22.85	10.11	-12.74	-55.76	-1
11	33	Lark bunting	54.45	24.84	-29.60	-54.37	-1
2	6	Brown creeper	22.36	11.09	-11.27	-50.40	-1
5	22	Rocky Mountain bighorn sheep (winter)	32.95	16.65	-16.29	-49.46	-1
8	29	Western bluebird	51.29	26.39	-24.90	-48.55	-1
2	6	Chestnut-backed chickadee	13.43	7.13	-6.30	-46.89	-1
2	11	White-winged crossbill	8.44	4.52	-3.92	-46.41	-1
2	6	Silver-haired bat	22.11	12.01	-10.10	-45.67	-1
12	36	Columbian sharp-tailed grouse (summer)	58.80	32.35	-26.44	-44.97	-1
2	5	Northern goshawk (summer)	22.75	12.93	-9.82	-43.16	-1
2	6	Hammond's flycatcher	22.11	12.91	-9.20	-41.59	-1
5	22	Rocky Mountain bighorn sheep (summer)	36.54	21.66	-14.88	-40.72	-1
2	5	American marten	18.82	11.54	-7.28	-38.67	-1
10	31	Short-eared owl	58.16	35.95	-22.21	-38.18	-1
10	31	Vesper sparrow	48.93	30.25	-18.68	-38.17	-1
10	32	Uinta ground squirrel	67.19	42.78	-24.41	-36.33	-1
2	4	Blue grouse (winter)	21.30	13.68	-7.62	-35.79	-1
10	31	Western meadowlark	54.80	35.23	-19.57	-35.71	-1
10	31	Lark sparrow	53.17	34.40	-18.76	-35.29	-1
2	6	Hoary bat	30.04	19.77	-10.27	-34.18	-1
2	9	Black-backed woodpecker	23.05	15.29	-7.77	-33.70	-1
10	31	Burrowing owl	72.68	48.89	-23.79	-32.73	-1
10	32	Preble's shrew	56.60	38.18	-18.42	-32.54	-1
6	25	Northern goshawk (winter)	21.37	14.59	-6.78	-31.73	-1
10	31	Ferruginous hawk	77.94	53.90	-24.04	-30.85	-1
11	33	Sage thrasher	60.90	43.56	-17.34	-28.47	-1
11	33	Brewer's sparrow	56.70	41.23	-15.47	-27.29	-1
11	33	Sage grouse (winter)	60.48	44.07	-16.41	-27.14	-1
7	28	Pallid bat	60.23	43.90	-16.33	-27.11	-1
11	33	Sage grouse (summer)	59.58	43.56	-16.02	-26.89	-1
11	33	Sagebrush vole	61.38	45.04	-16.35	-26.63	-1
11	33	Sage sparrow	77.61	57.09	-20.52	-26.45	-1

Table 7—Historical (H_S) and current (C_S) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_S), relative change (RCH_S), and trend categories (TC_S) of relative change^{a b} (continued)

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^c
-----Percentage-----							
10	31	Pronghorn	73.71	54.54	-19.18	-26.02	-1
1	1	White-breasted nuthatch	18.56	13.86	-4.69	-25.30	-1
5	22	California bighorn sheep	63.41	47.91	-15.50	-24.45	-1
4	18	Lazuli bunting	12.47	9.52	-2.95	-23.63	-1
2	6	Winter wren	7.86	6.01	-1.86	-23.62	-1
7	28	Western small-footed myotis	49.21	37.68	-11.53	-23.42	-1
11	33	Pygmy rabbit	63.54	48.68	-14.86	-23.38	-1
2	6	Varied thrush	11.24	8.67	-2.57	-22.86	-1
6	23	Rufous hummingbird	30.93	23.97	-6.96	-22.51	-1
2	13	Northern flying squirrel	32.26	25.26	-7.00	-21.70	-1
10	32	Ground snake	46.46	36.55	-9.91	-21.33	-1
2	6	Pileated woodpecker	10.62	8.40	-2.22	-20.88	-1
10	32	Striped whipsnake	80.20	63.68	-16.53	-20.61	-1
11	34	Black-throated sparrow	73.07	58.11	-14.96	-20.47	-1
11	35	Loggerhead shrike	47.82	38.45	-9.37	-19.60	0
2	5	Fisher	11.65	9.38	-2.27	-19.51	0
2	6	Golden-crowned kinglet	13.38	10.85	-2.54	-18.96	0
10	32	Longnose leopard lizard	74.35	60.66	-13.70	-18.42	0
7	28	Spotted bat	61.57	50.79	-10.79	-17.52	0
5	19	Grizzly bear	81.27	67.63	-13.64	-16.78	0
10	32	Wyoming ground squirrel	68.41	56.93	-11.48	-16.78	0
5	21	Long-eared owl	50.98	42.46	-8.52	-16.71	0
5	19	Gray wolf	83.82	70.71	-13.12	-15.65	0
6	23	Broad-tailed hummingbird	16.82	14.83	-1.99	-11.86	0
3	17	Blue grouse (summer)	30.41	26.94	-3.47	-11.42	0
7	26	Long-eared myotis	77.85	69.97	-7.87	-10.12	0
11	34	Kit fox	49.69	45.13	-4.56	-9.17	0
2	12	Woodland caribou	4.03	3.68	-0.36	-8.86	0
7	27	Townsend's big-eared bat	55.71	51.21	-4.50	-8.08	0
2	6	Vaux's swift	9.53	8.77	-0.76	-7.99	0
7	26	Yuma myotis	68.94	64.30	-4.64	-6.73	0
2	8	Great gray owl	26.53	24.94	-1.59	-5.99	0
10	32	Longnose snake	57.78	55.74	-2.04	-3.54	0
10	32	Mojave black-collared lizard	69.32	67.15	-2.17	-3.14	0
1	3	Western gray squirrel	22.43	22.03	-0.41	-1.81	0
NA	38	Gray-crowned rosy finch	8.34	8.34	-0.01	-0.09	0
10	32	White-tailed antelope squirrel	79.74	79.68	-0.05	-0.07	0
NA	38	Black rosy finch	10.87	10.87	0.00	0.00	0
NA	39	Lewis' woodpecker (resident population)	10.25	10.25	0.00	0.00	0
6	24	California mountain kingsnake	32.50	34.92	2.42	7.44	0

Table 7—Historical (H_S) and current (C_S) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_S), relative change (RCH_S), and trend categories (TC_S) of relative change^{a b} (continued)

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^c
----- <i>Percentage</i> -----							
5	20	Mountain goat	43.25	47.50	4.24	9.81	0
3	15	Pygmy shrew	68.11	76.68	8.56	12.57	0
6	24	Black-chinned hummingbird	20.20	23.10	2.90	14.37	0
3	15	Wolverine	32.83	37.57	4.73	14.41	0
3	16	Lynx	43.30	49.58	6.28	14.49	0
3	17	Mountain quail (summer)	25.51	29.61	4.10	16.09	0
7	26	Long-legged myotis	38.55	45.17	6.62	17.16	0
7	26	Fringed myotis	43.56	51.12	7.56	17.36	0
2	10	Olive-sided flycatcher	11.38	13.37	1.99	17.50	0
7	27	Pine siskin	29.95	35.21	5.26	17.56	0
2	11	Three-toed woodpecker	6.97	8.53	1.56	22.44	1
6	24	Sharptail snake	18.93	29.39	10.46	55.23	1
9	30	Bushtit	6.43	13.01	6.58	>100.00	2
9	30	Ash-throated flycatcher	6.61	14.28	7.67	>100.00	2
3	14	Hermit warbler	6.47	21.81	15.33	>100.00	2
NA	40	Brown-headed cowbird	0.00	33.67	33.67	>100.00	2

NA = not applicable.

^a Species are ranked by magnitude of relative change, with species whose source habitats were projected to have undergone the greatest declines listed first.

^b Calculations of historical and current estimates of extent of source habitats for each species excluded areas outside species ranges and also excluded those subwatersheds containing no source habitats both historically and currently. See “Assessing Change in Source Habitats from Historical to Current Conditions for Species and Groups” in the “Methods” section of volume 1 for further details about calculations of areal extent of source habitats and changes.

^c 5 trend categories were defined: -2, -1, 0, 1, and 2, where -2 = a decrease ≥ 60 percent; -1 = a decrease ≥ 20 percent and < 60 percent; 0 = a decrease or increase of < 20 percent; 1 = an increase ≥ 20 percent and < 60 percent; and 2 = an increase ≥ 60 percent.

Source habitats for another set of species declined less strongly at the basin scale (table 7), but declines were consistent across most ERUs (table 8). Examples included the lark sparrow, short-eared owl, vesper sparrow, western meadowlark, and blue grouse (winter). Source habitats for these species declined from 35 to 38 percent basin-wide, with categories of relative change of -1 or -2 in 75 to 85 percent of the ERUs (table 8). Other species whose source habitats declined across most ERUs (table 8; vol. 3, appendix 1, table 5) included the ground snake, burrowing owl, longnose leopard lizard, Preble’s shrew, Uinta ground squirrel, lark bunting, clay-colored sparrow, Hammond’s

flycatcher, and black-throated sparrow; source habitats for these species declined in more than 70 percent of the ERUs in which these species occurred.

Source habitats for some species also showed extremely strong declines—at or near 100 percent—for particular ERUs (vol. 3, appendix 1, table 5), even though basin-wide declines or declines across many ERUs were not as strong. For example, source habitats for summer habitat of northern goshawk declined 93 to 97 percent in the Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork ERUs (vol. 3, appendix 1, table 5), but basin-wide decline was weaker (-43 percent, table 7). Likewise, declines in source habitats for American marten and fisher ranged

Table 8—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_S) of relative change for each of 91 broad-scale species of focus^{a b}

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
1	2	Lewis' woodpecker (migrant population)	11	100	0	0
10	32	Ground snake	2	100	0	0
10	32	Washington ground squirrel	4	100	0	0
12	36	Columbian sharp-tailed grouse (summer)	11	91	9	0
12	37	Grasshopper sparrow	11	91	9	0
5	22	Rocky Mountain bighorn sheep (winter)	9	89	11	0
1	1	Pygmy nuthatch	13	85	15	0
10	31	Burrowing owl	13	85	15	0
10	31	Short-eared owl	13	85	15	0
10	31	Vesper sparrow	13	85	15	0
2	5	Flammulated owl	13	85	8	8
2	6	Williamson's sapsucker	13	85	0	15
8	29	Western bluebird	11	82	18	0
1	1	White-headed woodpecker	9	78	22	0
5	22	Rocky Mountain bighorn sheep (summer)	9	78	22	0
10	31	Western meadowlark	13	77	23	0
2	4	Blue grouse (winter)	13	77	15	8
10	31	Lark sparrow	13	77	15	8
2	6	Brown creeper	13	77	8	15
10	32	Longnose leopard lizard	8	75	25	0
10	32	Preble's shrew	12	75	25	0
10	32	Uinta ground squirrel	4	75	25	0
11	33	Lark bunting	4	75	25	0
12	37	Clay-colored sparrow	4	75	0	25
11	33	Sagebrush vole	11	73	18	9
11	34	Black-throated sparrow	7	71	29	0
5	22	California bighorn sheep	10	70	30	0
7	28	Pallid bat	10	70	30	0
10	31	Ferruginous hawk	10	70	30	0
10	31	Pronghorn	10	70	30	0
10	32	Striped whipsnake	10	70	30	0
2	7	Boreal owl	10	70	20	10
2	5	Northern goshawk (summer)	13	69	15	15
2	6	Hammond's flycatcher	13	69	15	15
2	6	Silver-haired bat	13	69	15	15
11	33	Brewer's sparrow	12	67	33	0
12	37	Idaho ground squirrel	3	67	33	0
11	33	Sage grouse (summer)	12	67	25	8
11	33	Sage grouse (winter)	12	67	25	8
2	9	Black-backed woodpecker	12	67	8	25
11	33	Sage thrasher	11	64	36	0
11	33	Sage sparrow	11	64	36	0

Table 8—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_S) of relative change for each of the 91 broad-scale species of focus^{a b} (continued)

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
1	1	White-breasted nuthatch	13	62	31	8
7	28	Western small-footed myotis	13	62	31	8
11	35	Loggerhead shrike	13	62	23	15
11	33	Pygmy rabbit	10	60	30	10
2	11	White-winged crossbill	10	60	10	30
2	12	Woodland caribou	5	60	0	40
6	23	Broad-tailed hummingbird	7	57	14	29
6	23	Rufous hummingbird	13	54	31	15
2	13	Northern flying squirrel	13	54	23	23
2	5	American marten	13	54	8	38
6	25	Northern goshawk (winter)	13	54	8	38
2	5	Fisher	13	54	0	46
11	34	Kit fox	4	50	50	0
2	6	Chestnut-backed chickadee	10	50	20	30
3	17	Blue grouse (summer)	13	46	15	38
4	18	Lazuli bunting	13	46	15	38
2	6	Golden-crowned kinglet	13	46	8	46
2	11	Three-toed woodpecker	13	46	0	54
1	3	Western gray squirrel	7	43	43	14
2	8	Great gray owl	12	42	17	42
2	6	Winter wren	12	42	0	58
10	32	Wyoming ground squirrel	5	40	60	0
7	27	Townsend's big-eared bat	13	38	46	15
2	6	Varied thrush	11	36	9	55
5	19	Grizzly bear	13	31	62	8
2	6	Hoary bat	13	31	54	15
5	21	Long-eared owl	13	31	54	15
2	10	Olive-sided flycatcher	13	31	15	54
2	6	Pileated woodpecker	10	30	10	60
2	6	Vaux's swift	11	27	0	73
7	28	Spotted bat	12	25	58	17
5	20	Mountain goat	8	25	38	38
6	24	California mountain kingsnake	4	25	25	50
5	19	Gray wolf	13	23	77	0
6	24	Black-chinned hummingbird	13	23	23	54
7	27	Pine siskin	13	23	8	69
10	32	White-tailed antelope squirrel	5	20	80	0
7	26	Long-eared myotis	13	15	85	0
3	15	Wolverine	13	15	15	69
3	16	Lynx	9	11	67	22
3	17	Mountain quail (summer)	9	11	33	56
7	26	Yuma myotis	11	9	91	0

Table 8—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_S) of relative change for each of 91 broad-scale species of focus^{a b} (continued)

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
10	32	Mojave black-collared lizard	2	0	100	0
10	32	Longnose snake	1	0	100	0
NA	38	Black rosy finch	7	0	100	0
NA	38	Gray-crowned rosy finch	11	0	100	0
NA	39	Lewis' woodpecker (resident population)	1	0	100	0
7	26	Fringed myotis	11	0	73	27
3	15	Pygmy shrew	5	0	60	40
7	26	Long-legged myotis	13	0	54	46
9	30	Bushtit	9	0	22	78
9	30	Ash-throated flycatcher	9	0	11	89
3	14	Hermit warbler	4	0	0	100
6	24	Sharptail snake	3	0	0	100
NA	40	Brown-headed cowbird	13	0	0	100

NA = not applicable; these species not assigned to families.

^a Trend categories were defined such that -2 = a decrease ≥ 60 percent; -1 = a decrease ≥ 20 percent and < 60 percent; 0 = a decrease or increase of < 20 percent; 1 = an increase ≥ 20 percent and < 60 percent; and 2 = an increase ≥ 60 percent.

^b Species are listed in descending order by percentage of ERUs with a trend category of -1 or -2. Percentages were calculated only for ERUs where the species occurred.

from 88 to 100 percent within the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Upper Snake ERUs (vol. 3, appendix 1, table 5), whereas basin-wide decline was less strong for both species (-39 percent for marten, -20 percent for fisher, table 7). Source habitats for sagebrush vole also declined 87 and 98 percent within the Northern Cascades and Snake Headwaters ERUs, respectively (vol. 3, appendix 1, table 5), but basin-wide decline was 27 percent (table 7).

In contrast to the large number of species whose source habitats declined across many or most ERUs, relatively few species were associated with source habitats that changed little across most ERUs. Source habitats for only 16 species had a trend category of relative change equal to 0 for most ERUs in which these species occurred (table 8). Moreover, an even smaller number of species were associated with source habitats that increased strongly across most ERUs. For example, only five species—brown-headed cowbird, sharptail snake, hermit warbler, ash-throated

flycatcher, and bushtit—had source habitats that increased by > 50 percent basin-wide (table 7) and had categories of relative change of 1 or 2 in > 75 percent of the ERUs in which these species occurred (table 8). Cover type-structural stage combinations that contributed most to increases in source habitats for these five species were cropland-hay-pasture (associated with brown-headed cowbird), juniper woodlands (associated with ash-throated flycatcher and bushtit), various lower elevation cover types in the stem-exclusion and understory-reinitiation stages (associated with sharptail snake), and some of the lower elevation cover types in the managed young-forest stages (associated with hermit warbler here) (vol. 3, appendix 1, table 4).

Habitat Change on All Lands Versus Public and Mixed Ownership

Species whose relative change in source habitats was negative on all lands also had relative change that was negative on public and mixed ownership (figs. 6A,

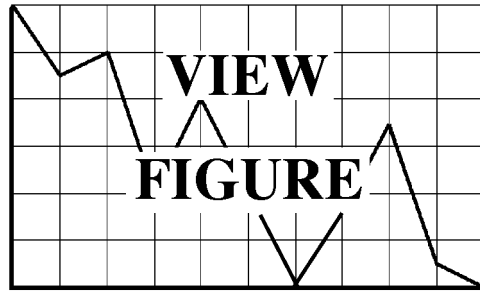


Figure 6—Relative change (RCH_S) in source habitats, from historical to current periods, for each of 91 species (97 species-seasonal entries), on all lands versus public and mixed-ownership lands at the scale of the basin.

and 6B); that is, basin-wide trends in source habitats that were negative on all lands also were consistently negative on public and mixed ownership, for all species whose habitat trends had a negative sign basin-wide. The only exception was the great gray owl, which showed a slightly negative trend on all lands but a slightly positive trend on public and mixed ownership (fig. 6B). Similarly, species whose relative change in source habitats was positive on all lands also had relative change that was positive on public and mixed ownership (fig. 6B). One exception existed: the California mountain kingsnake, whose source habitats showed a slightly positive trend on all lands but a slightly negative trend on public and mixed ownership (fig. 6B).

Magnitude of relative change in source habitats on all lands versus public and mixed ownership also was highly consistent. Magnitude of decline or increase nearly always was stronger for all lands than for public and mixed ownership (figs. 6A, B), but overall differences in magnitude typically were <10 percent between all lands versus public and mixed ownership. Exceptions were chestnut-backed chickadee, broad-tailed hummingbird, woodland caribou, and western gray squirrel, whose source habitats showed a slightly stronger decline on public and mixed ownership than on all lands (fig. 6A). Additional exceptions were olive-sided flycatcher and three-toed woodpecker, whose source habitats showed a slightly stronger increase on public and mixed ownership than on all lands (fig. 6B).

Management Implications

The large number of species whose source habitats declined strongly or very strongly at the basin scale (table 7), combined with the diverse composition and structure of the source habitats of these species (vol. 3, appendix 1, table 1), suggest that no particular species or habitats, or small set of species or habitats, are easily identified as needing priority management. Rather, the large number of species undergoing decline in source habitats, combined with the diversity of habitats associated with these species, suggest that aggregations of large numbers of species and a wide array of source habitats may need management attention.

Species-level findings also suggest that it would be difficult to select a small number of management indicator or umbrella species on which to base management (see “Glossary,” Landres and others 1988, and Marcot and others 1994 for definitions and concepts of indicator and umbrella species). Moreover, the large number of species whose source habitats declined at the basin scale further suggests that any attempts to group or aggregate species must be made without losing unique, single-species trends in source habitats that could be obscured or diluted by such attempts. This potential problem has been the main criticism directed at the use of guilds (Szaro 1986) or indicator guilds (Verner 1984) for management applications. Thus, it is important that management needs of the many species undergoing a strong or very strong decline in source habitats (tables 7 and 8; vol. 3, appendix 1, table 5) be accounted for in group- and family-level methods and results that are part of our assessment. Species-level trends summarized at the ERU level (table 8; vol. 3, appendix 1, table 5) are particularly important to consider for species whose source habitats exhibited strongly different trends among ERUs.

The high consistency in direction and magnitude of change in source habitats for each species between all lands and public-mixed ownership lands further suggests that the same habitat issues likely are of interest to both public and private land managers. That is, both public and private land managers, or regulatory managers with potential jurisdiction related to both public and private lands, would be faced with the same or a similar direction and magnitude of habitat trends, regardless of land ownership. It is important to note, however, that this finding may not hold at finer scales within the basin—such as subwatershed and watershed scales—where large differences in direction and magnitude of habitat trends may exist between land ownerships.

Group-Level Results and Discussion

Group Membership and Associated Source Habitats

Results are presented here for 40 groups, composed of 91 species of birds, mammals, and reptiles (table 5). With the exception of two species, the black rosy

finch and gray-crowned rosy finch, each species depends on a unique set of source habitats (vol. 3, appendix 1, table 1). Species within each group, however, display strong overlap in the cover type-structural stage combinations used as source habitats, as intended by our use of cluster analysis to group species based on their degree of similarity and dissimilarity in source habitats (see “Methods,” “Clustering the Species into Groups”). The specific terrestrial communities and cover type-structural stage combinations identified as source habitats for each species in each group are shown in volume 3, appendix 1, table 1.

Results and discussion presented here for the 40 groups represent an overview of more detailed results and discussion presented in volume 2. Readers should refer to volume 2 for results, by groups of species, that display (1) the geographic range of each species within each group; (2) maps of the percentage of area of source habitats, historically and currently; (3) a map of habitat change; and (4) bar charts displaying the percentage of watersheds in each ERU that have undergone positive, strongly positive, neutral, negative, and strongly negative relative change in source habitats from historical to current conditions. Discussion in volume 2 also contains detailed interpretation of habitat change in relation to associated vegetation dynamics, in relation to conditions of other habitat features, and in relation to nonvegetative factors that affect species within each group. Finally, discussion in volume 2 also includes a description of key management implications. Management implications were synthesized from results of our assessment, from the scientific literature, and from results of prior assessments conducted as part of the ICBEMP. Implications include an identification of management issues associated with species in each group, and a list of strategies and practices that might be useful in dealing with those issues. An overview of these results and their implications is described in the following sections.

Habitat Change by Basin and Ecological Reporting Unit

Basin-wide change—Fifty percent of the 40 groups of species were associated with source habitats that declined strongly or very strongly from historical to current periods, based on trend categories of relative change (TC_G) at the basin scale (rank of -1 or -2, table 9). By contrast, only four groups (10 percent) were

associated with source habitats that increased strongly or very strongly (rank of 1 or 2), but a moderate number—16 groups or 40 percent—were associated with source habitats that showed little change (rank of 0).

In contrast to the trends based on categories of relative change, decline in source habitats was consistently more negative when expressed as continuous variables of absolute and relative change (ACH_G and RCH_G). By using these measures, 75 percent of the groups were associated with a decline in source habitats (table 9). Only one group showed no change in source habitats, and 23 percent of groups were associated with an increase.

As with species-level results, groups of species whose source habitats declined were associated with many forested and rangeland environments. Of the 20 groups that underwent the strongest relative decline in source habitats (table 9), 9 are primarily dependent on forested habitats, another 9 are largely dependent on rangeland habitats, and 2 are dependent on a combination of forested and rangeland habitats (vol. 3, appendix 1, table 1). Again, as with the species-level results, this finding indicates that many source habitats have declined in the basin; in turn, this suggests that no particular species or habitats, or small set of species or habitats, are easily identified as needing priority management.

Habitat change by ecological reporting unit—

Groups of species whose source habitats declined strongly or very strongly at the basin scale (trend categories of relative change of -1 or -2, table 9) also experienced strong declines in source habitats across most ERUs (table 10; vol. 3, appendix 1, table 3). For example, group 36, composed of the clay-colored sparrow, grasshopper sparrow, and Idaho ground squirrel, had the second greatest relative decline among all groups of species in the basin (-71 percent, table 9) and also had categories of relative change that were -1 or -2 for 91 percent of the ERUs in which these species occurred (table 10). Other groups whose source habitats declined strongly at the basin level and across most or all ERUs included group 2 (migrant population of Lewis’ woodpecker (group 2), group 36 (Columbian sharp-tailed grouse), group 31 (Ferruginous hawk, burrowing owl, short-eared owl, vesper sparrow, lark sparrow, western meadowlark, and pronghorn), group 29 (western bluebird), and group 4 (blue grouse [winter]). Source habitats for these groups declined by >35 percent at the basin scale (table 9),

Table 9—Historical (H_G) and current (C_G) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 40 groups of 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_G), relative change (RCH_G), and trend categories (TC_G) of relative change^a

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^b
-----Percentage-----							
1	2	Lewis' woodpecker (migrant population)	13.78	2.29	-11.49	-83.35	-2
12	37	Clay-colored sparrow Grasshopper sparrow Idaho ground squirrel	21.22	6.17	-15.05	-70.93	-2
2	7	Boreal owl	14.97	5.78	-9.20	-61.42	-2
1	1	White-headed woodpecker White-breasted nuthatch Pygmy nuthatch	18.37	9.01	-9.36	-50.96	-1
8	29	Western bluebird	51.29	26.39	-24.90	-48.55	-1
12	36	Columbian sharp-tailed grouse (summer)	58.80	32.35	-26.44	-44.97	-1
2	5	Northern goshawk (summer) Flammulated owl American marten Fisher	18.10	10.74	-7.37	-40.70	-1
10	31	Ferruginous hawk Burrowing owl Short-eared owl Vesper sparrow Lark sparrow Western meadowlark Pronghorn	57.06	36.55	-20.52	-35.95	-1
2	4	Blue grouse (winter)	21.30	13.68	-7.62	-35.79	-1
2	6	Vaux's swift Williamson's sapsucker Pileated woodpecker Hammond's flycatcher Chestnut-backed chickadee Brown creeper Winter wren Golden-crowned kinglet Varied thrush Silver-haired bat Hoary bat	13.94	9.07	-4.88	-34.99	-1

Table 9—Historical (H_G) and current (C_G) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 40 groups of 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_G), relative change (RCH_G), and trend categories (TC_G) of relative change^a (continued)

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^b
-----Percentage-----							
2	9	Black-backed woodpecker	23.05	15.29	-7.77	-33.70	-1
10	32	Mojave black-collared lizard	66.42	45.22	-21.20	-31.91	-1
		Longnose leopard lizard					
		Striped whipsnake					
		Longnose snake					
		Ground snake					
		Preble's shrew					
		White-tailed antelope squirrel					
		Washington ground squirrel					
		Wyoming ground squirrel					
		Uinta ground squirrel					
6	25	Northern goshawk (winter)	21.37	14.59	-6.78	-31.73	-1
5	22	California bighorn sheep	50.51	34.64	-15.87	-31.42	-1
		Rocky Mountain bighorn sheep (summer)					
		Rocky Mountain bighorn sheep (winter)					
11	33	Sage grouse (summer)	54.61	39.20	-15.41	-28.21	-1
		Sage grouse (winter)					
		Sage thrasher					
		Brewer's sparrow					
		Sage sparrow					
		Lark bunting					
		Pygmy rabbit					
		Sagebrush vole					
4	18	Lazuli bunting	12.47	9.52	-2.95	-23.63	-1
7	28	Western small-footed myotis	49.97	38.73	-11.24	-22.49	-1
		Spotted bat					
		Pallid bat					
11	34	Black-throated sparrow	64.72	50.46	-14.25	-22.02	-1
		Kit fox					
2	13	Northern flying squirrel	32.26	25.26	-7.00	-21.70	-1
6	23	Rufous hummingbird	30.20	23.67	-6.54	-21.64	-1
		Broad-tailed hummingbird					
11	35	Loggerhead shrike	47.82	38.45	-9.37	-19.60	0
5	21	Long-eared owl	50.98	42.46	-8.52	-16.71	0
5	19	Gray wolf	82.42	69.07	-13.35	-16.20	0
		Grizzly bear					

Table 9—Historical (H_G) and current (C_G) estimates of areal extent (percentage of area) of source habitats at the scale of the basin for 40 groups of 91 broad-scale species of focus, and resulting changes in source habitats based on three measures: absolute change (ACH_G), relative change (RCH_G), and trend categories (TC_G) of relative change^a (continued)

Family	Group	Common name	Historical estimate	Current estimate	Absolute change	Relative change	Trend category ^b
-----Percentage-----							
2	12	Woodland caribou	4.03	3.68	-0.36	-8.86	0
3	17	Blue grouse (summer) Mountain quail (summer)	28.57	26.34	-2.23	-7.80	0
7	27	Pine siskin Townsend's big-eared bat	51.75	48.39	-3.36	-6.49	0
2	8	Great gray owl	26.53	24.94	-1.59	-5.99	0
7	26	Yuma myotis Long-eared myotis Fringed myotis Long-legged myotis	55.64	53.94	-1.70	-3.05	0
1	3	Western gray squirrel	22.43	22.03	-0.41	-1.81	0
NA	38	Black rosy finch Gray-crowned rosy finch	8.17	8.16	-0.01	-0.09	0
NA	39	Lewis' woodpecker (resident)	10.25	10.25	0	0	0
2	11	Three-toed woodpecker White-winged crossbill	6.91	7.53	0.62	8.90	0
5	20	Mountain goat	43.25	47.50	4.24	9.81	0
6	24	Sharptail snake California mountain kingsnake Black-chinned hummingbird	20.33	23.15	2.82	13.86	0
3	16	Lynx	43.30	49.58	6.28	14.49	0
2	10	Olive-sided flycatcher	11.38	13.37	1.99	17.50	0
3	15	Pygmy shrew Wolverine	35.87	43.08	7.21	20.11	1
9	30	Ash-throated flycatcher Bushtit	5.96	12.63	6.67	>100.00	2
3	14	Hermit warbler	6.47	21.81	15.33	>100.00	2
NA	40	Brown-headed cowbird	0	33.67	33.67	>100.00	2

NA = not applicable; these species not assigned to families.

^a Calculations of historical and current estimates of extent of source habitats for each group excluded areas outside species ranges and also excluded those subwatersheds containing no source habitats both historically and currently. See "Assessing Change in Source Habitats From Historical to Current Conditions for Species and Groups" in the "Methods" section of volume 1 for further details.

^b 5 trend categories were defined: -2, -1, 0, 1, and 2, where -2 = a decrease ≥ 60 percent; -1 = a decrease ≥ 20 percent and < 60 percent; 0 = a decrease or increase of < 20 percent; 1 = an increase ≥ 20 percent and < 60 percent; and 2 = an increase ≥ 60 percent.

and categories of relative change were either -1 or -2 in >70 percent of the ERUs in which these species occurred (table 10; vol. 3, appendix 1, table 3).

Other groups whose source habitats declined strongly across most ERUs included group 32 (Mojave black-collared lizard, longnose leopard lizard, striped whip-snake, longnose snake, ground snake, Preble's shrew, white-tailed antelope squirrel, Washington ground squirrel, Wyoming ground squirrel, and Uinta ground squirrel), group 22 (California and Rocky Mountain bighorn sheep), group 33 (sage grouse, sage thrasher, Brewer's sparrow, sage sparrow, lark bunting, pygmy rabbit, and sagebrush vole), group 34 (black-throated sparrow and kit fox), group 7 (boreal owl), and group 1 (white-headed woodpecker, white-breasted nuthatch, and pygmy nuthatch). Source habitats for these groups declined in >65 percent of the ERUs in which the groups occurred (table 10; vol. 3, appendix 1, table 3).

Source habitats for some groups also exhibited extremely strong declines—at or near 100 percent—for particular ERUs (vol. 3, appendix 1, table 3), even though trends were not consistent across ERUs. For example, source habitats for group 6 (northern goshawk [summer], flammulated owl, American marten, and fisher) declined >90 percent in the Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork ERUs (vol. 3, appendix 1, table 3), but trends were neutral or increasing in almost 40 percent of the ERUs (table 10). Likewise, decline in source habitats for group 9 (black-backed woodpecker) ranged from 86 to 94 percent within the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Upper Snake ERUs (vol. 3, appendix 1, table 5), but trends were neutral or increasing in >30 percent of ERUs. Source habitats for group 18 (lazuli bunting) also underwent similar declines—ranging from 82 to 93 percent—within the Upper Klamath, Blue Mountains, and Lower Clark Fork ERUs (vol. 3, appendix 1, table 5), but almost 40 percent of the ERUs for this group had a neutral or increasing trend.

In contrast to the large number of groups whose source habitats declined across many or most ERUs, relatively few groups were associated with source habitats that changed little across most ERUs. Specifically, source habitats for five groups had categories of relative change of 0 for most ERUs in which the groups

occurred (table 10). Similarly, six groups were associated with source habitats that increased strongly across most ERUs (table 10).

Habitat Change on All Lands Versus Public and Mixed Ownership

The direction of trends in source habitats between all lands versus public and mixed ownership for groups of species (fig. 7) was similar to that found for individual species (fig. 6); that is, basin-wide trends in source habitats that were negative on all lands also were consistently negative on public and mixed ownership, for all groups whose habitat trends had a negative sign basin-wide. One exception existed: group 8 (great gray owl), which showed a slightly negative trend on all lands but a slightly positive trend on public and mixed ownership (fig. 7). Similarly, groups whose relative change in source habitats was positive on all lands also had relative change that was positive on public and public mixed ownership (fig. 7).

Magnitude of relative change in source habitats on all lands versus public and mixed ownership also showed the same highly consistent pattern for groups of species (fig. 7) as that found for individual species (fig. 6). Magnitude of decline or increase nearly always was stronger for all lands than on public and mixed ownership (fig. 7), but overall differences in magnitude most often were <10 percent. Exceptions were group 4 (blue grouse [winter]), group 12 (woodland caribou), group 19 (gray wolf and grizzly bear), and group 3 (western gray squirrel), whose source habitats showed a slightly stronger decline on public and mixed ownership than on all lands (fig. 7). Additional exceptions were group 11 (loggerhead shrike) and group 10 (olive-sided flycatcher), whose source habitats showed a slightly stronger increase on public and mixed ownership than on all lands (fig. 7).

Correlation of Habitat Trends Among Species Within Groups

Relative change in source habitats was positively correlated ($P < 0.05$) for all of the 177 species pairings within the multi-species groups (fig. 8). Moreover, the grand mean of all correlation coefficients, calculated from the means of all within-group coefficients, was relatively high ($r = 0.66$). By contrast, the grand mean

Table 10—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_G) of relative change for each of the 40 groups of 91 broad-scale species of focus^{a b}

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
1	2	Lewis' woodpecker (migrant population)	11	100	0	0
12	36	Columbian sharp-tailed grouse (summer)	11	91	9	0
12	37	Clay-colored sparrow Grasshopper sparrow Idaho ground squirrel	11	91	9	0
10	31	Ferruginous hawk Burrowing owl Short-eared owl Vesper sparrow Lark sparrow Western meadowlark Pronghorn	13	85	15	0
10	32	Mojave black-collared lizard Longnose leopard lizard Striped whipsnake Longnose snake Ground snake Preble's shrew White-tailed antelope squirrel Washington ground squirrel Wyoming ground squirrel Uinta ground squirrel	13	85	15	0
8	29	Western bluebird	11	82	18	0
2	4	Blue grouse (winter)	13	77	15	8
5	22	California bighorn sheep Rocky Mountain bighorn sheep (summer) Rocky Mountain bighorn sheep (winter)	13	77	23	0
11	33	Sage grouse (summer) Sage grouse (winter) Sage thrasher Brewer's sparrow Sage sparrow Lark bunting Pygmy rabbit Sagebrush vole	12	75	25	0
11	34	Black-throated sparrow Kit fox	8	75	25	0

Table 10—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_G) of relative change for each of the 40 groups of 91 broad-scale species of focus^{a b} (continued)

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
2	7	Boreal owl	10	70	20	10
1	1	White-headed woodpecker White-breasted nuthatch Pygmy nuthatch	13	69	23	8
2	9	Black-backed woodpecker	12	67	8	25
2	5	Northern goshawk (summer) Flammulated owl American marten Fisher	13	62	15	23
7	28	Western small-footed myotis Spotted bat Pallid bat	13	62	38	0
11	35	Loggerhead shrike	13	62	23	15
2	12	Woodland caribou	5	60	0	40
2	6	Vaux's swift Williamson's sapsucker Pileated woodpecker Hammond's flycatcher Chestnut-backed chickadee Brown creeper Winter wren Golden-crowned kinglet Varied thrush Silver-haired bat Hoary bat	13	54	23	23
2	13	Northern flying squirrel	13	54	23	23
6	23	Rufous hummingbird Broad-tailed hummingbird	13	54	31	15
6	25	Northern goshawk (winter)	13	54	8	38
2	11	Three-toed woodpecker White-winged crossbill	13	46	0	54
4	18	Lazuli bunting	13	46	15	38
1	3	Western gray squirrel	7	43	43	14

Table 10—Percentage of ecological reporting units (ERUs) having various combinations of trend categories (TC_G) of relative change for each of the 40 groups of 91 broad-scale species of focus^{a b} (continued)

Family	Group	Common name	Number of ERUs	Percentage of ERUs in category -1 or -2	Percentage of ERUs in category 0	Percentage of ERUs in category 1 or 2
2	8	Great gray owl	12	42	17	42
7	27	Pine siskin Townsend's big-eared bat	13	38	23	38
3	17	Blue grouse (summer) Mountain quail (summer)	12	33	25	42
2	10	Olive-sided flycatcher	13	31	15	54
5	19	Gray wolf Grizzly bear	13	31	69	0
5	21	Long-eared owl	13	31	54	15
5	20	Mountain goat	8	25	38	38
6	24	Sharptail snake California mountain kingsnake Black-chinned hummingbird	13	23	23	54
3	16	Lynx	9	11	67	22
3	15	Pygmy shrew Wolverine	13	8	23	69
7	26	Yuma myotis Long-eared myotis Fringed myotis Long-legged myotis	13	8	92	0
3	14	Hermit warbler	4	0	0	100
9	30	Ash-throated flycatcher Bushtit	10	0	20	80
NA	38	Black rosy finch Gray-crowned rosy finch	11	0	100	0
NA	39	Lewis' woodpecker (resident population)	1	0	100	0
NA	40	Brown-headed cowbird	13	0	0	100

NA = not applicable; these species not assigned to families.

^a Groups are listed in descending order by percentage of ERUs with a trend category of -1 or -2.

^b Trend categories were defined such that -2 = a decrease ≥ 60 percent; -1 = a decrease ≥ 20 percent and < 60 percent; 0 = a decrease or increase of < 20 percent; 1 = an increase ≥ 20 percent and < 60 percent; and 2 = an increase ≥ 60 percent.

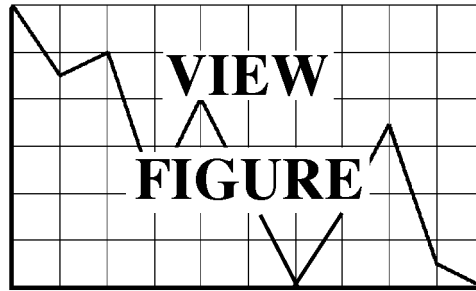


Figure 7—Relative change (RCH_G) in source habitats, from historical to current periods, for each of 40 groups of broad-scale species of focus, on all lands versus public lands and mixed-ownership lands at the scale of the basin.

of all between-group species pairings was near zero ($r = 0.02$), further suggesting that clustering of species into groups efficiently captured similar direction and magnitude of species-level trends within each multi-species group.

Range of coefficients between individual species within each group varied widely, however, with r values as high as 0.96, and as low as 0.12. Despite this wide range, only 5 of the 177 coefficients (<3 percent) calculated for the within-group species pairings were <0.20 (fig. 8): (1) pygmy shrew and wolverine ($r = 0.12$, group 15); (2) long-eared myotis and long-legged myotis ($r = 0.15$, group 26); (3) long-eared myotis and fringed myotis ($r = 0.17$, group 26); (4) Wyoming ground squirrel and longnose snake ($r = 0.18$, group 32); and (5) Wyoming ground squirrel and Mojave black-collared lizard ($r = 0.18$, group 32). In five other cases (<3 percent), correlation coefficients were >0.20 but <0.40: (1) California mountain

kingsnake and black-chinned hummingbird ($r = 0.33$, group 24); (2) long-legged myotis and Yuma myotis ($r = 0.33$, group 26); (3) white-tailed antelope squirrel and Wyoming ground squirrel ($r = 0.30$, group 32); (4) white-tailed antelope squirrel and longnose snake ($r = 0.35$, group 32); and (5) white-tailed antelope squirrel and Mojave black-collared lizard ($r = 0.36$, group 32);

Notably, 9 of the 10 correlation coefficients <0.40 involved just five species—long-legged myotis, Wyoming ground squirrel, white-tailed antelope squirrel, longnose snake, and Mojave black-collared lizard—as a member of a species pairing. Also, the 10 coefficients <0.40 involved just 4 groups: 15, 24, 26, and 32. Finally, of the 11 species that were part of one or more pairings where r was <0.40, all 11 (100 percent) were associated with trend categories for source habitats that were neutral (table 7); this is especially

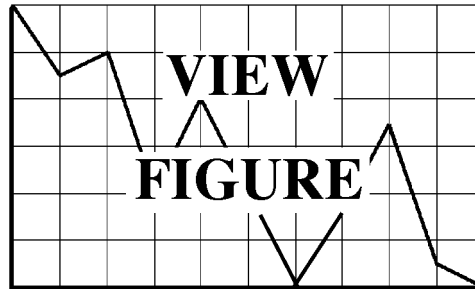


Figure 8—Mean and range of correlation coefficients for species pairings within each group of broad-scale species of focus for groups containing more than one species. Mean for each group was calculated from Kendall's Tau correlation coefficients that were computed for each pair of species in the group. Single values are for groups containing two species (one coefficient for the one pair). Range of values is shown for groups containing 3 or more species. Specific pairings are identified for any pair of species with a correlation coefficient less than 0.4, which is denoted by the upper dotted line. The lower dotted line denotes the mean correlation coefficient (0.02) for all species pairings between groups.

noteworthy considering that habitats for most of the species underwent strong or very strong declines (trend categories of relative change of -1 or -2, table 7).

Management Implications

The large number of groups of species whose source habitats declined strongly or very strongly at the basin scale (trend categories of relative change of -1 or -2, table 9), combined with the diverse composition and structure of the source habitats of these species (vol. 3, appendix 1, table 1), suggests that no particular species or habitats, or small set of species or habitats, are easily identified as needing priority management. Rather, the large number of species undergoing decline in source habitats, combined with the diversity of habitats associated with these species, suggests that aggregations of large numbers of species and a wide array of source habitats may need management attention.

Consequently, our findings suggest that habitat analysis and management of groups of species may be more efficient than a species-by-species approach. This point is especially germane, considering the large number of species (91 species and 97 species seasonal entries) analyzed here, and the consistent pattern shown between trends in source habitats at the species level versus trends for the same species calculated as groups (for example, examine trends in table 7 versus table 9).

The high consistency in direction and magnitude of change in source habitats for each group between all lands and public-mixed ownership lands further suggests that the same habitat issues may be of interest to both public and private land managers. That is, both public and private land managers, or regulatory managers with potential jurisdiction related to both public and private lands, would be faced with the same or a similar direction and magnitude of habitat trends,

regardless of land ownership. This finding, however, may not hold at finer scales within the basin—such as subwatershed and watershed scales—where large differences in direction and magnitude of habitat trends may exist between land ownerships.

The relatively high, positive correlation coefficients that we calculated for most within-group species pairings versus the relatively low or negative coefficients calculated for between-group species pairings, have the following implications for interpretation of our group-level habitat trends:

1. The strong, positive correlations in habitat trends among species within most of the groups indicate that group-level results accurately represent individual species trends; this is especially encouraging, considering that most groups having strong correlations in their species-level habitat trends also were the groups that contained species associated with strong or very strong declines in source habitats. In these cases, the group-level trends reflected the species-level trends. This implication is especially important, considering that most attention presumably will be given to species and groups whose source habitats have undergone the strongest declines. In these cases, our group-level results appear most reliable.
2. The few groups containing species with low coefficients—namely groups 15, 24, 26, and 32—may yield group-level trends that could be misleading for one or more species within the groups. Many of the species involved in pairings having low correlation coefficients, however, are localized in their distributions, and thus have little effect on group-level trends. Examples are white-tailed antelope squirrel, Wyoming ground squirrel, longnose snake, Mojave black-collared lizard, and California mountain kingsnake. In these cases, the species-level contribution to the group trend is minor because ranges of the problem species (vol. 2, fig. 96) are narrow and thus do not contribute to calculation of habitat trend for most areas of the basin in which group-level trends were calculated. (See “Methods” for details about calculation of group-level trends in source habitats).
3. Implementation procedures presumably will consider results of our correlation analysis and account for the handful of low correlations as part

of local analysis. The species listed in figure 8 and their associated groups are candidates for more detailed analysis as part of implementation.

Because of the accuracy and efficiency with which group-level trends reflect species-level changes in source habitats, we have emphasized and provided detailed results and management implications based on indepth analyses for all 40 groups of species in volume 2. An especially noteworthy section of volume 2 is the comprehensive set of issues, strategies, and practices identified for effective management of each group of species, as well as the synthesis of supporting, pertinent empirical literature about environmental requirements and population status and trends of each species in each group.

Family-Level Results and Discussion

Habitat Relations Among Families

Placement of 37 of the groups into 12 families (fig. 5, table 6) by using a combination of cluster analysis and empirical knowledge of similarities of species in habitat requirements resulted in distinct differences among families in the number of terrestrial community types and source habitats used (table 11). Family 4 had the most restricted number of terrestrial community types and source habitats used by species of any family, with habitats restricted to early-seral forests (table 11). Species in family 1 also were restricted to a small number of terrestrial community types, and in this case, the types were composed of low-elevation, late-seral forests (table 11). By contrast, species in family 2 used a higher number and variety of terrestrial community types that encompassed all elevations of late-seral forests. Species in family 3 used an even greater variety of forested conditions; habitats encompassed the highest number and type of source habitats within the highest number of terrestrial community types of any family dependent on forested habitats.

Species dependent strictly on rangelands were placed in families 10, 11 and 12. Species in families 11 and 12 were restricted to a relatively small number of terrestrial community types, with family 11 primarily dependent on sagebrush, and family 12 dependent on grassland and open-canopy sagebrush habitats (table 11). Species in family 10 used a broader set of

[illegible]

Table 11 - Pages 63–64

terrestrial communities, consisting of a greater variety of grassland, shrubland, woodland, and related cover types than those used by families 11 and 12.

Species in families 5, 6, 7, 8, and 9 were associated with various terrestrial community types, but each family's set of source habitats was distinctly different from the others (table 11). Habitats for species in family 9 were restricted to relatively few source habitats within the upland woodland and upland shrubland types. By contrast, species in family 5 used habitats that encompassed nearly all terrestrial community types. Species in family 6 also used various terrestrial communities, with the types composed of forests, woodlands, and montane shrubs. Terrestrial community types used by family 7 were similar to those used by family 6, with the main difference being the use of sagebrush types instead of montane shrubs. Finally, habitats for family 8 spanned a fairly restrictive but unusual combination of terrestrial community types composed of both early- and late-seral forests, as well as woodland, shrubland, and grassland types (table 11).

These differences in terrestrial communities and source habitats among the families resulted in distinctly different habitat trends for each family. In the following sections, we present results for each family and an overview of results across families. Results are summarized in terms of key vegetative themes, trends, and issues presumably of most interest to managers of FS- and BLM-administered lands within the basin. Specifically, the family-level results provide (1) a description of source habitats and special habitat features for species in the family; (2) a summary of family-level trends in source habitats from historical to current periods; (3) identification of the primary causes for the observed habitat trends and the ecological processes associated with the causes; and (4) a synthesis of broad-scale strategies that would benefit species and their source habitats.

Overview of Family-Level Results

The 12 families exhibited wide variation in the percentage of ERUs that had declining versus increasing or neutral habitat trends (table 12). Family 1 had the largest percentage of ERUs (85 percent, 11 of 13 ERUs) with declining trends (see "Methods," "Evaluating Change in Source Habitats by Family," for analysis steps used to characterize ERU habitat trends by family). Other families for which most of

the ERUs had declining habitat trends included family 8 (82 percent, 9 of 11 ERUs), family 10 (69 percent, 9 of 13 ERUs), and families 4 and 12 (each 62 percent, 8 of 13 ERUs). A substantial percentage of ERUs also had declining trends for family 2 (46 percent, 6 of 13) and family 11 (39 percent, 4 of 13). Smaller percentages of ERUs had declining trends for family 6 (31 percent, 4 of 13), family 5 (23 percent, 3 of 13), family 7 (15 percent, 2 of 13), family 9 (10 percent, 1 of 10), and family 3 (8 percent, 1 of 12).

As found for the species and groups, declining habitat trends for families were associated with several species whose source habitats encompassed a diversity of forest and rangeland environments. For example, families 1, 4, 8, 10, and 12, which had the highest percentage of ERUs with negative habitat trends, were associated with source habitats as diverse as low-elevation, old-forest (family 1), early-seral forest (family 4), a combination of rangeland and early- and late-seral forest (family 8), herbland, shrubland, and woodland (family 10), and grassland and open-canopy sagebrush (family 12). In addition, nearly all families (even those with a small number of ERUs with declining habitat trends) contained one or more groups of species whose source habitats declined strongly or very strongly from historical to current periods (based on trend categories of relative change (TC_G) at the basin scale [rank of -1 or -2, table 9]). Exceptions were families 3 and 9, neither of which included groups having a declining trend category at the basin scale (table 9).

Management implications—Family-level habitat trends suggest that no particular species or habitats, or small set of species or habitats, are easily identified as needing priority management. This is because (1) several families had predominantly negative habitat trends across ERUs (table 12), (2) nearly all families contained groups of species whose source habitats declined strongly or very strongly at the basin scale (table 9), and (3) declining source habitats were diverse in composition and structure (vol. 3, appendix 1, table 1). The large number of species, spanning multiple groups and families, that experienced declines in source habitats, combined with the diversity of habitats associated with these species, suggest that aggregations of large numbers of species and a wide array of source habitats may need management attention.

Table 12—Percentage of watersheds in 3 trend categories for each family, by ecological reporting unit (ERU)

Family	ERU	ERU name	Percentage of watersheds decreasing	Percentage of watersheds neutral	Percentage of watersheds increasing	Dominant trend ^a
1	1	Northern Cascades	69	24	7	Decreasing
1	2	Southern Cascades	56	22	22	Decreasing
1	3	Upper Klamath	33	19	48	Neutral
1	4	Northern Great Basin	47	8	45	Neutral
1	5	Columbia Plateau	51	19	31	Decreasing
1	6	Blue Mountains	67	20	13	Decreasing
1	7	Northern Glaciated Mountains	94	5	2	Decreasing
1	8	Lower Clark Fork	95	4	1	Decreasing
1	9	Upper Clark Fork	77	20	3	Decreasing
1	10	Owyhee Uplands	77	3	20	Decreasing
1	11	Upper Snake	81	0	19	Decreasing
1	12	Snake Headwaters	86	4	10	Decreasing
1	13	Central Idaho Mountains	57	33	9	Decreasing
2	1	Northern Cascades	74	13	13	Decreasing
2	2	Southern Cascades	37	15	47	Neutral
2	3	Upper Klamath	7	5	88	Increasing
2	4	Northern Great Basin	18	10	71	Increasing
2	5	Columbia Plateau	44	10	46	Neutral
2	6	Blue Mountains	47	17	36	Neutral
2	7	Northern Glaciated Mountains	92	5	3	Decreasing
2	8	Lower Clark Fork	89	8	3	Decreasing
2	9	Upper Clark Fork	97	2	1	Decreasing
2	10	Owyhee Uplands	41	18	41	Neutral
2	11	Upper Snake	52	23	25	Decreasing
2	12	Snake Headwaters	75	17	8	Decreasing
2	13	Central Idaho Mountains	43	22	35	Neutral
3	1	Northern Cascades	17	45	37	Neutral
3	2	Southern Cascades	0	20	80	Increasing
3	3	Upper Klamath	5	7	88	Increasing
3	4	Northern Great Basin	7	23	70	Increasing
3	5	Columbia Plateau	23	25	52	Increasing
3	6	Blue Mountains	7	15	78	Increasing
3	7	Northern Glaciated Mountains	22	37	41	Neutral
3	8	Lower Clark Fork	47	40	13	Neutral
3	9	Upper Clark Fork	71	17	13	Decreasing
3	10	Owyhee Uplands	35	15	50	Neutral
3	11	Upper Snake	10	19	71	Increasing
3	12	Snake Headwaters	14	41	45	Neutral
3	13	Central Idaho Mountains	21	48	31	Neutral
4	1	Northern Cascades	30	8	63	Increasing
4	2	Southern Cascades	45	13	42	Neutral
4	3	Upper Klamath	98	0	2	Decreasing
4	4	Northern Great Basin	69	0	31	Decreasing

Table 12—Percentage of watersheds in 3 trend categories for each family, by ecological reporting unit (ERU) (continued)

Family	ERU	ERU name	Percentage of watersheds decreasing	Percentage of watersheds neutral	Percentage of watersheds increasing	Dominant trend ^a
4	5	Columbia Plateau	83	2	15	Decreasing
4	6	Blue Mountains	53	4	42	Decreasing
4	7	Northern Glaciated Mountains	81	7	11	Decreasing
4	8	Lower Clark Fork	96	3	2	Decreasing
4	9	Upper Clark Fork	81	9	10	Decreasing
4	10	Owyhee Uplands	47	8	45	Neutral
4	11	Upper Snake	59	13	28	Decreasing
4	12	Snake Headwaters	21	7	72	Increasing
4	13	Central Idaho Mountains	35	13	52	Increasing
5	1	Northern Cascades	29	54	17	Neutral
5	2	Southern Cascades	17	44	39	Neutral
5	3	Upper Klamath	9	50	41	Neutral
5	4	Northern Great Basin	4	90	6	Neutral
5	5	Columbia Plateau	59	39	2	Decreasing
5	6	Blue Mountains	34	48	17	Neutral
5	7	Northern Glaciated Mountains	36	43	22	Neutral
5	8	Lower Clark Fork	48	43	9	Neutral
5	9	Upper Clark Fork	82	13	5	Decreasing
5	10	Owyhee Uplands	20	80	0	Neutral
5	11	Upper Snake	60	40	0	Decreasing
5	12	Snake Headwaters	43	38	19	Neutral
5	13	Central Idaho Mountains	18	52	30	Neutral
6	1	Northern Cascades	43	36	21	Neutral
6	2	Southern Cascades	39	39	22	Neutral
6	3	Upper Klamath	5	14	81	Increasing
6	4	Northern Great Basin	13	13	74	Increasing
6	5	Columbia Plateau	28	7	65	Increasing
6	6	Blue Mountains	54	15	31	Decreasing
6	7	Northern Glaciated Mountains	63	22	15	Decreasing
6	8	Lower Clark Fork	93	3	4	Decreasing
6	9	Upper Clark Fork	87	11	2	Decreasing
6	10	Owyhee Uplands	27	18	55	Increasing
6	11	Upper Snake	18	27	55	Increasing
6	12	Snake Headwaters	34	19	47	Neutral
6	13	Central Idaho Mountains	48	22	30	Neutral
7	1	Northern Cascades	36	52	13	Neutral
7	2	Southern Cascades	5	51	44	Neutral
7	3	Upper Klamath	9	29	62	Increasing
7	4	Northern Great Basin	7	86	7	Neutral
7	5	Columbia Plateau	47	29	24	Neutral
7	6	Blue Mountains	23	46	31	Neutral
7	7	Northern Glaciated Mountains	25	55	20	Neutral
7	8	Lower Clark Fork	55	37	8	Decreasing

Table 12—Percentage of watersheds in 3 trend categories for each family, by ecological reporting unit (ERU) (continued)

Family	ERU	ERU name	Percentage of watersheds decreasing	Percentage of watersheds neutral	Percentage of watersheds increasing	Dominant trend ^a
7	9	Upper Clark Fork	44	38	18	Neutral
7	10	Owyhee Uplands	24	71	5	Neutral
7	11	Upper Snake	63	29	8	Decreasing
7	12	Snake Headwaters	42	30	29	Neutral
7	13	Central Idaho Mountains	34	36	30	Neutral
8	1	Northern Cascades	81	6	13	Decreasing
8	2	Southern Cascades	76	15	8	Decreasing
8	3	Upper Klamath	64	24	12	Decreasing
8	4	Northern Great Basin	10	83	7	Neutral
8	5	Columbia Plateau	77	22	1	Decreasing
8	6	Blue Mountains	90	8	2	Decreasing
8	7	Northern Glaciated Mountains	88	3	9	Decreasing
8	8	Lower Clark Fork	99	0	1	Decreasing
8	9	Upper Clark Fork	89	5	6	Decreasing
8	10	Owyhee Uplands	24	76	0	Neutral
8	13	Central Idaho Mountains	79	15	6	Decreasing
9	1	Northern Cascades	60	0	40	Decreasing
9	2	Southern Cascades	38	29	32	Neutral
9	3	Upper Klamath	17	8	75	Increasing
9	4	Northern Great Basin	7	4	89	Increasing
9	5	Columbia Plateau	5	10	85	Increasing
9	6	Blue Mountains	34	7	59	Increasing
9	7	Northern Glaciated Mountains	0	0	100	Increasing
9	10	Owyhee Uplands	9	25	66	Increasing
9	11	Upper Snake	9	9	81	Increasing
9	12	Snake Headwaters	33	11	56	Increasing
10	1	Northern Cascades	50	10	40	Neutral
10	2	Southern Cascades	57	16	27	Decreasing
10	3	Upper Klamath	77	9	14	Decreasing
10	4	Northern Great Basin	10	88	1	Neutral
10	5	Columbia Plateau	71	28	1	Decreasing
10	6	Blue Mountains	70	19	11	Decreasing
10	7	Northern Glaciated Mountains	92	4	4	Decreasing
10	8	Lower Clark Fork	85	8	8	Decreasing
10	9	Upper Clark Fork	67	11	22	Decreasing
10	10	Owyhee Uplands	16	84	0	Neutral
10	11	Upper Snake	65	35	0	Decreasing
10	12	Snake Headwaters	68	10	22	Decreasing
10	13	Central Idaho Mountains	35	37	28	Neutral
11	1	Northern Cascades	47	45	8	Neutral
11	2	Southern Cascades	47	23	30	Neutral
11	3	Upper Klamath	20	59	20	Neutral
11	4	Northern Great Basin	11	86	2	Neutral

Table 12—Percentage of watersheds in 3 trend categories for each family, by ecological reporting unit (ERU) (continued)

Family	ERU	ERU name	Percentage of watersheds decreasing	Percentage of watersheds neutral	Percentage of watersheds increasing	Dominant trend ^a
11	5	Columbia Plateau	50	33	17	Neutral
11	6	Blue Mountains	43	41	16	Neutral
11	7	Northern Glaciated Mountains	54	31	15	Decreasing
11	8	Lower Clark Fork	100	0	0	Decreasing
11	9	Upper Clark Fork	58	30	13	Decreasing
11	10	Owyhee Uplands	24	72	4	Neutral
11	11	Upper Snake	76	22	2	Decreasing
11	12	Snake Headwaters	82	14	3	Decreasing
11	13	Central Idaho Mountains	42	30	27	Neutral
12	1	Northern Cascades	95	5	0	Decreasing
12	2	Southern Cascades	86	11	4	Decreasing
12	3	Upper Klamath	93	2	4	Decreasing
12	4	Northern Great Basin	11	88	1	Neutral
12	5	Columbia Plateau	80	19	1	Decreasing
12	6	Blue Mountains	78	11	12	Decreasing
12	7	Northern Glaciated Mountains	96	1	2	Decreasing
12	8	Lower Clark Fork	100	0	0	Decreasing
12	9	Upper Clark Fork	65	4	31	Decreasing
12	10	Owyhee Uplands	45	53	2	Neutral
12	11	Upper Snake	31	65	5	Neutral
12	12	Snake Headwaters	48	28	25	Neutral
12	13	Central Idaho Mountains	45	12	43	Neutral

^a ERUs were classified as increasing or decreasing if >50 percent of the watersheds had positive or negative trends, respectively. ERUs not classified as increasing or decreasing were classified as neutral. See “Forming Families of Groups to Summarize Results Among Multiple Groups” in “Methods” section for details about assigning trends to watersheds.

Correlation of Habitat Trends Among Species Within Families

Relative change in source habitats was positively correlated ($P < 0.05$) for 520 (94 percent) of the 556 within-family species pairings for the 10 families that contained multiple species. Only 36 within-family species pairings were not correlated ($P > 0.05$), and only 3 (<1 percent) were negatively correlated ($P < 0.05$). Moreover, the grand mean of all correlation coefficients, calculated from the means of all species pairings within each family, was relatively high ($r = 0.52$). Mean coefficients for each family, however, varied from a low of 0.23 (family 3) to a high of 0.96 (family 9).

In general, the mean within-family coefficients were higher for families whose species were associated with a smaller, more specialized set of source habitats, and progressively lower for families whose species were associated with an increasingly larger, more diverse set of habitats. For example, mean within-family coefficients were 0.53 and 0.55 for the two families whose source habitats were restricted largely to old-forest stages (families 1 and 2). Mean within-family coefficients were similarly high (0.60 to 0.72) for the three families whose source habitats were wholly or largely restricted to rangelands (families 10, 11, and 12), and highest (0.96) for the family with the most restricted set of source habitats (family 9). By contrast, mean within-family coefficients ranged from 0.23 to 0.34 for the four families whose source habitats either spanned a broad range of forest structural

stages (family 3) or encompassed diverse combinations of forest and rangeland habitats (families 5, 6, and 7).

Management implications—The correlation coefficients for species pairings within each family were less positive and more variable relative to the coefficients calculated for species pairings within each group (fig. 8). For example, <3 percent of the within-group species pairings had coefficients that were <0.20, but 6 percent of the within-family species pairings had coefficients <0.20. Moreover, the grand mean of all coefficients for the within-group species pairings was 0.66, whereas the grand mean of all within-family coefficients was 0.52.

The more variable and less positive coefficients of species pairings within families versus those within groups is not surprising, given the more diverse set of habitats associated with species within each family versus group. These results have the following implications for any management strategy that relies on family-level habitat trends:

1. Use of the family-level habitat trends for habitat management is a coarse-filter approach. Coarse-filter management assumes that managing an appropriate amount and arrangement of all representative land areas and habitats will provide for the needs of all associated species (Hunter 1991) (see “Methods,” “Designing a Hierarchical System of Single- and Multi-species Assessment”). Such an assumption, by using family-level habitat trends as the basis for a coarse-filter approach, would be tenuous when applied to individual subbasins, watersheds, or subwatersheds, given the family-level correlation results. A coarse-filter approach that relies on family-level habitat trends can likely be effective, however, in devising credible broad-scale ecosystem strategies across large geographic areas of the basin. Such family-level strategies will be more accurate and defensible when devised for areas as large as individual or multiple ERUs, or for large numbers of subbasins or watersheds. If subbasins or watersheds are used as the basis for devising family-level strategies, a minimum of 5 to 10 subbasins or 75 to 150 watersheds would be needed; such areas would provide sufficient accuracy (based on table 2) to detect the most dominant habitat trends common to most species and groups in a family, and provide sufficient geographic coverage

to dampen some or much of the species variability in family-level habitat trends that occur on individual watersheds or small collections of watersheds.

2. Any coarse-filter approach based on family-level habitat trends should include an analysis of how well such an approach accommodates habitat needs for each group of species and for individual species that have been identified as having undergone strong, widespread declines in aerial extent of source habitats. Such an analysis would test how well the coarse-filter approach meets the needs of species or groups that likely require highest management attention, and allow for the coarse-filter approach to be “fine-tuned” to ensure its effectiveness for all species. For example, managers may not be compelled to devise a habitat strategy for the “Forest and Range Mosaic Family” (family 5) because most family-level trends were neutral or positive (table 12); closer examination of group-level trends within the family, however, shows that trends for group 22 (composed of California and Rocky Mountain bighorn sheep) were largely negative for most ERUs (table 10) and for the basin as a whole (table 9). Managers should check for and accommodate such results in their broad-scale ecosystem strategies.

Family 1—Low-Elevation, Old-Forest Family

Groups 1, 2, and 3 compose family 1 (table 6). These three groups include the white-headed woodpecker, white-breasted nuthatch, pygmy nuthatch, migratory population of Lewis’ woodpecker, and western gray squirrel (table 6). Ranges of these species are shown in figures 3, 6, and 9 of volume 2.

Source habitats and special habitat features—All species in family 1 depend on late-seral multi- and single-storied lower montane forests as source habitats (table 11). Some family members also use old-forest cover types in the upper montane, riparian woodlands, and upland woodlands community groups (table 11; vol. 3, appendix 1, table 1). Source habitats for family 1 occur in all ERUs, but habitats were never common. Historically, these habitats typically composed less than 25 percent of the area in most watersheds (vol. 2, figs. 4a, 7a, and 10a). Today, source habitats for family 1 (vol. 2, figs. 4b, 7b, and 10b) still occur in all 13 ERUs but are particularly scarce within the Columbia



Figure 9—Trend in source habitats for family 1 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

Plateau, Upper Snake, Northern Great Basin, and Owyhee Uplands. In the remaining nine ERUs, source habitats are more common but still compose <25 percent of most watersheds.

All species in family 1 require large-diameter (>53 cm [21 in]) snags or trees with cavities for nesting, foraging, or both (vol. 3, appendix 1, table 2). The possible exception is the western gray squirrel, which uses cavities of snags and large hollow trees for nesting and resting, but these structures may not be a requirement (Ryan and Carey 1995). The Lewis' woodpecker is associated closely with recent burns and responds favorably to stand-replacing fires (see Tobalske 1997), whereas habitat for other species in family 1 is usually maintained by frequent, low-intensity burns that retain old-forest structure.

Broad-scale changes in source habitats—Source habitats declined in 70 percent of watersheds basin-wide between the historical and current periods (fig. 9). Thirteen percent of watersheds had increasing trends, and the remaining 17 percent were stable. Eleven ERUs exhibited declining trends in >50 percent of watersheds (table 12). The only ERUs with predominantly neutral trends were the Upper Klamath and Northern Great Basin ERUs, and of these, the Northern Great Basin ERU contained little habitat historically.

Declines in source habitats for family 1 are related largely to reductions in the old-forest lower montane community type. Declines in both late-seral single-layered and late-seral multi-layered lower montane occurred in all ERUs that had declining habitat trends, and these declines were considered ecologically significant except for the old-forest multi-layered stage in the Blue Mountains and Central Idaho Mountains (Hann and others 1997).

The importance of restoration for species in this family is highlighted by the magnitude of the declines. Basin-wide, the current extent of late-seral single-layered lower montane forests represents an 81-percent decline in the historical areal extent, and the extent of multi-layered forests represents a 35-percent decline (Hann and others 1997). These declines were particularly pronounced in the Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork, where nearly 100 percent of these community types have been lost (Hann and others 1997). Declines in source

habitats for family 1 are among the most widespread and strongest of any declines observed for any set of species that we included in our analysis.

Primary causes for habitat trends and the associated ecological processes—Timber harvest and fire exclusion were the two primary causes for the widespread, strong decline in source habitats for family 1 (Hann and others 1997). Timber harvest has resulted in the replacement of late-seral, lower montane source habitats with mid-seral forests. Fire exclusion has resulted in a gradual shift in stand composition from shade-intolerant tree species such as ponderosa pine to shade-tolerant species such as Douglas-fir and grand fir. Additionally, human occupancy of and use of lands that historically supported lower montane forests have increased and presumably contributed to declines in source habitats.

The magnitude of decline in historical vegetation structure and composition has been greater for the lower montane community group than any other forest community groups (Hann and others 1997), partly because lower elevation forests were more accessible for logging and contained high-value, large-diameter timber. Moreover, lower elevation forests historically were subject to more frequent, light surface or underburn fire events; structures in these forests therefore were more susceptible to decreases in fire frequency than were forests at higher elevations. This combination of intensive harvest of the larger overstory trees and the exclusion of fire has created an environment favorable for the increase of shade-tolerant trees characteristic of the montane community group. The resulting forest structure and composition is not suitable for many species in family 1 because of greater density of small-diameter trees and logs, and changed species composition. For example, high stand density can make foraging difficult for the Lewis' woodpecker, an aerial insectivore, and can reduce vigor of oaks used by western gray squirrels for foraging. The loss of large-diameter trees and large snags can limit the abundance of nesting structures for the white-breasted nuthatch, pygmy nuthatch, white-headed woodpecker, and Lewis' woodpecker. A concurrent decline in large down logs has occurred, which may be of concern for other species associated with this group.

Source habitats for family 1 also shifted geographically across large areas of the basin since historical times (see fig. 9). Source habitats that underwent no change or an increase are now farther south (fig. 9) and represent a warmer average environment. Many of these environments with increasing amounts of habitat are only increasing because of fire exclusion in what would have been fire-maintained savannahs dominated by shrubs or herbs with scattered large trees. Environments with neutral changes in habitat have a complex combination of areas with (1) slow succession rates, such that change in response to fire exclusion has not affected broad-scale cover type and structural stage composition; or (2) a neutralizing mix of late-seral forest increases from fires exclusion in savannah types and decreases from timber harvest. The habitats where declines occurred are to the north with cooler average temperatures and higher habitat productivity.

Finally, extensive fragmentation of historical landscape patterns has occurred in lower elevation watersheds that support habitats of family 1 (Hann and others 1997, Hessburg and others 1999). Broad-scale departure as a result of fragmented ownership patterns, high road densities, and timber harvest occurred in 8 of the 13 ERUs.

Restoration of source habitats will be difficult for family 1 because the existing composition and structure of vegetation represents a substantial departure from historical conditions. The current vegetation is more susceptible to stand-replacing fires and increasingly vulnerable to insect- and disease-related tree mortality. These conditions may require active management to restore more desirable forest structure and composition.

Other factors affecting the family—Roads may facilitate a reduction in the density of large-diameter trees and snags as habitat for family 1, as suggested by the lower density of large-diameter trees, snags, and logs associated with roaded areas (Hann and others 1997). Roads also likely facilitate the legal and illegal shooting of western gray squirrels in association with increased human access provided by roads.

Issues and strategies for conservation—The following issues and strategies for family 1 relate to declines in source habitats and special habitat features.

Issues—

1. Basin-wide decline in late-seral interior and Pacific ponderosa pine and large (>53 cm [21 in]) overstory and emergent trees.
2. Basin-wide loss of large-diameter snags (>53 cm [21 in]).
3. Declines in old-forest aspen and cottonwood/willow.
4. Declines in shrub and herb understories of montane and lower montane forests in response to increased density of small trees and downed wood, litter, and duff.
5. Loss or decline of oak trees as a cover type and within other cover types.
6. Fragmentation of lower elevation landscape patterns.
7. Exclusion of light surface or underburn fires that occurred frequently and extensively.
8. Broad-scale shift of family 1 habitats to environments with warmer average temperatures.

Strategies—The following strategies could be considered to address issues related to species belonging to family 1:

- 1a. (To address issue no. 1) Retain stands of interior and Pacific ponderosa pine where old-forest conditions are present, and manage to promote their long-term sustainability through the use of prescribed burning and understory thinning.
- 1b. (To address issue no. 1) Primarily in the northern parts of the basin where old forests have transitioned to mid-seral stages, identify mid-seral stands that could be brought into old-forest conditions in the near future and use appropriate silvicultural activities to encourage this development.
2. (To address issue no. 2) As a short-term strategy retain all large-diameter (>53 cm [21 in] d.b.h.) ponderosa pine, cottonwood, Douglas-fir, and western larch snags within the basin, preferably in clumps, and provide opportunities for snag recruitment throughout the montane and lower montane



Figure 10—Trend in source habitats for family 2 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

communities. As a long-term strategy, conduct mid-scale assessment of species snag use and the dynamics of snags in landscapes and adjust the strategy or groups of subbasins.

3. (To address issue no. 3) Within all ERUs with cottonwood-willow stands, maintain existing old forests, and identify younger stands for eventual development of old-forest structural conditions. Return natural hydrologic regimes to large river systems, particularly in the Central Idaho Mountains, Upper Snake, and Snake Headwaters ERUs where large riparian cottonwood woodlands still remain.
4. (To address issue no. 4) Rejuvenate and enhance shrub and herb understory of lower montane community groups (old-forest ponderosa pine) in the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Blue Mountains ERUs. Throughout the range of the Lewis' woodpecker, allow some stand-replacing wildfires to burn in lower montane wilderness and other lands managed with a natural process emphasis (for example designated wilderness, research natural areas, and areas of critical environmental concern). Such opportunities can be found particularly in the Central Idaho Mountains, Blue Mountains, and Snake Headwaters ERUs, and in western Montana. Minimize mechanized harvest and site-preparation activities that increase susceptibility to exotic and noxious weed invasion, soil erosion, or high densities of tree regeneration.
5. (To address issue no. 5) Manage for the maintenance and restoration of oak woodlands, particularly along the eastern flank of the Cascade Range within and between existing populations of western gray squirrel.
6. (To address issue no. 6) Look for opportunities to acquire lands in lower elevation forest and forest-rangeland mosaics. Close and restore excess roads to reduce fragmentation of landscapes by roads. Use thinning to repattern landscapes to a more native condition. Where natural process areas occur, prioritize road closures and restoration in adjacent watershed to increase the interior core of habitats with native patterns.
7. (To address issue no. 7) Continue a strategy of wildfire suppression of stand-replacing fires except where such fires would benefit habitat for Lewis'

woodpecker under the conditions specified in issue no. 4. Use prescribed fire, timber harvest, and thinning to change forest composition and structure to reduce risk of stand-replacing wildfires and shift to maintenance with prescribed underburn fires.

Family 2—Broad-Elevation, Old-Forest Family

Family 2 consists of 24 species of birds and mammals within groups 4 to 13 (table 6). Example species are marten, fisher, flammulated owl, northern goshawk, pileated woodpecker, boreal owl, northern flying squirrel, and black-backed woodpecker. Ranges of each species in family 2 are shown in figures 12, 15, 18, 21, 24, 27, 30, 33, 36, and 39, volume 2.

Source habitats and special habitat features—All species in family 2 use late-seral multi- and single-layered stages of the montane community as source habitats. Source habitats for some species also include late-seral stages of the subalpine community or the lower montane community, or both (table 11). In addition, source habitats for the northern flying squirrel include the understory reinitiation stage of most cover types within subalpine, montane, lower montane, and riparian woodland communities. Source habitats for family 2 overlap those of family 1 but encompass a broader array of cover types and elevations than habitats for family 1 (vol. 3, appendix 1, table 1). Species of family 1 are primarily restricted to lower elevation forests of interior Douglas-fir and ponderosa pine forests.

Fifteen species in family 2 depend on snags for nesting or foraging; four of these species also use down logs to meet life requisites; four species also use large, hollow trees (vol. 3, appendix 1, table 2). Downed logs, lichens, and fungi of late-seral forests provide habitat for many prey species of northern goshawk, flammulated owl, boreal owl, great gray owl, fisher, and marten (Gibilsco and others 1995, Hayward and Verner 1994, Reynolds and others 1992, Thompson and Colgan 1987). Stand-replacing, large burns and other beetle-infested stands provide high concentrations of prey (wood-boring beetles) for three-toed and black-backed woodpeckers (Koplin 1969). Juxtaposition of early- and late-seral stages is needed to meet all aspects of life functions for the silver-haired bat, hoary bat, and great gray owl, which are identified as contrast species (see "Glossary," vol. 3).

Late-seral source habitats used by marten, fisher, and boreal owl, however, may be negatively affected by increased fragmentation brought about by juxtaposing their need for late-seral habitats with early-seral habitats (Hargis 1996, Hayward and Verner 1994, Jones 1991). Thus, the negative response of marten, fisher, and boreal owl to juxtaposition of their source habitats with forest openings versus the positive response of silver-haired bat, hoary bat, and great gray owl to these same conditions must be considered when managing the spatial arrangement of early- versus late-seral habitats for species in family 2.

Broad-scale changes in source habitats—Source habitats for family 2 declined in most watersheds. Basin-wide, 59 percent of watersheds exhibited declining trends, 28 percent increased, and the remaining 13 percent were neutral (fig. 10). Watersheds with declining trend were concentrated in the northern part of the basin and in the Snake River drainage; those with increasing trend were mostly in the south-central and southwestern areas of the basin (fig. 10). The Northern Cascades, Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, Upper Snake, and Snake Headwaters ERUs had declining trends in more than 50 percent of their watersheds (table 12). The Blue Mountains, Central Idaho Mountains, and Columbia Plateau had predominantly neutral trends, but nevertheless, each of these ERUs had a substantial percentage of watersheds with declining trends: 47 percent in the Blue Mountains, 43 percent in the Central Idaho Mountains, and 44 percent in the Columbia Plateau (table 12). Watersheds with increasing trends were concentrated in the Upper Klamath and Northern Great Basin ERUs (table 12; fig. 10). Abundance of source habitats in the Northern Great Basin, however, was minor as there are few watersheds within this ERU that contain source habitats for family 2.

Although source habitats for family 2 declined in most watersheds, not all species-level trends for members of family 2 exhibited a declining trend. Exceptions were three-toed woodpecker, Vaux's swift, great gray owl, and woodland caribou (tables 7, 8). Source habitats for the three-toed woodpecker exhibited positive trends, and those of the woodland caribou and great gray owl were neutral primarily because their habitats do not include the lower elevation old forests of Sierra Nevada mixed-conifer, western white pine, or ponderosa pine (vol. 3, appendix 1, table 1), which generally declined more than upper elevational cover types

(vol. 3, appendix 1, table 4). Source habitats of the Vaux's swift were neutral primarily because of its unique combination of source habitats and range distribution. That is, Vaux's swift uses only the montane terrestrial community, which had a mixture of declining and increasing trends in areal extent basin-wide (Hann and others 1997; vol. 3, appendix 1, table 4), and its range does not include the Snake Headwaters and Upper Snake ERUs (vol. 2, fig. 18), where significant declining trends were projected for family 2.

Primary causes for habitat trends and the associated ecological processes—Timber harvest techniques, exclusion of fire, and resulting changes in insect and disease infestation dynamics are the primary causes for trends in source habitats for family 2. Suppression of wildfires has resulted in a shift in stand composition from shade-intolerant to shade-tolerant species within lower montane, montane, and subalpine communities. Timber harvest activities have had a similar effect, favoring the removal of shade-intolerant tree species (such as western larch, western white pine, and ponderosa pine), and the retention and growth of shade-tolerant understories, which are more susceptible to fire, insect, and disease (such as grand fir, western redcedar, western hemlock, and Douglas-fir).

Declines in source habitats were particularly associated with late-seral lower montane single-layer forest, which was projected to have had an 80-percent decline in areal extent since the historical period and with late-seral subalpine multi-layer forest, which had a projected decline of 64 percent (Hann and others 1997). Although of less magnitude, declines also occurred in late-seral forests of the montane and subalpine terrestrial communities. There was an ecologically significant increase in the late-seral single-layer subalpine community, but this only affected a relatively small area. The areal extent of late-seral lower montane, montane, and subalpine forests were found to be below their historical minimum in 78, 59, and 63 percent of the subbasins, respectively (Hann and others 1997).

There was a substantial spatial shift from historical to current in the distribution of family 2 habitat that was somewhat similar to that of family 1 (see fig. 10). As with family 1, the areas with neutral or increasing trends were generally in the southern part of the basin, whereas the areas with decreasing trends were farther north. Patterns of family 2 are not, however, identical to those for family 1. Family 2 habitats often increased

where family 1 habitats were neutral. This is generally because successional processes are more rapid in the montane and subalpine environments than they are in lower montane environments, so these habitats for family 2 responded more quickly to fire suppression than those for family 1.

As with family 1, the areas of greatest decline are to the north or in the high elevations of the Snake Headwaters where the combination of timber harvest, fire exclusion, and insect-disease mortality of stressed trees is causing a shift to mid-seral or early-seral forests. The area of greatest increase was in the Upper Klamath where there were vast increases in both single-layer and multi-layer montane old forests (Hann and others 1997). These late-seral forests in the Klamath, however, have been extensively affected by selective harvest and fire exclusion and may not have old-forest characteristics at the mid scale (Hessburg and others 1999).

Other factors affecting the family—Roads increase human access into source habitats and have the potential to negatively affect most species in family 2. Fourteen species in family 2 rely on snags for nesting and foraging, and snag densities are lower in roaded versus unroaded areas of the basin (Hann and others 1997). Survival of marten and fisher can decline because of fur harvesting if trapping is not regulated carefully (Fortin and Cantin 1994, Jones 1991, Quick 1956). Roads potentially increase trapping pressure on marten and fisher, resulting in significantly higher captures in roaded versus unroaded areas (Hodgman and others 1994) and in logged versus unlogged areas (Thompson 1994). Roads also increase mortality of woodland caribou. Fatal collisions with automobiles occur on open roads in woodland caribou habitat (Scott and Servheen 1985). A high percentage of the annual mortality in the 1980s was attributed to illegal harvest by hunters and poachers (Scott and Servheen 1985), and both legal and illegal take of other ungulate species have been facilitated by road access (for example, Cole and others 1997).

Patterns of road density also are associated with departures from the historical landscape patterns. Broad-scale landscape patterns were found to be highly fragmented in correlation with low to moderate elevation and proximity to moderate or higher road densities (Hann and others 1997). Fragmentation and substantial declines of the late-seral lower montane

forests, simplification of the montane forest, and fragmentation of the subalpine forest resulted in broad-scale departures from historical landscape patterns for 8 of the 13 ERUs (Hann and others 1997).

Issues and strategies for conservation—The primary issues for family 2 relate to source habitats, special habitat features, and road-related human disturbances.

Issues—

1. Declines in late-seral forests of subalpine, montane, and lower montane communities and associated attributes such as large trees, large snag, large down logs, lichen, and fungi.
2. Tradeoffs between source habitats for species in family 2 and habitats for species in family 1.
3. Balancing the fragmentation of late-seral habitats for marten, fisher, and boreal owl versus juxtaposition of early- and late-seral habitats for silver-haired bat, hoary bat, and great gray owl.
4. Broad-scale departures from historical landscape patterns.
5. Negative effects of road-related human activities.
6. Reduction in the extent of frequent, light underburning and light surface fires.

Strategies—The following strategies could be considered to address issues related to species belonging to family 2. It is important that source habitats for both families 1 and 2 be considered together in the design of conservation strategies. For example, efforts to restore the composition and structure of lower montane forests may involve thinning or the use of fire in areas where shade-tolerant species now dominate. Such areas currently serve as source habitats for many species in family 2. Consequently, the maintenance of an appropriate network of these habitats would be essential for restoring lower montane forests in a manner that provides for both families.

The historical ranges of area covered by these habitats could be used as one guide to establishing this balance (Hann and others 1997). In addition, the disturbance processes that create and maintain these habitats could be considered in determining where habitats are to be maintained. Sites where shade-tolerant species are at

lower risk of broad-scale loss because of insects, disease, and fire could be managed to maintain those habitats for family 2, whereas areas prone to frequent disturbance could be managed to simulate the disturbance processes that historically maintained the composition and structure of lower montane forests and thereby benefit family 1.

A similar strategy could be used in the ERUs where habitat has clearly increased for both families, such as parts of the Southern Cascades, Upper Klamath, and Northern Great Basin. Here, both families would benefit from retention of a network of old-forest habitats with management also aimed at increasing the extent of fire-maintained communities.

The following strategies have been developed to address issues related to the species in family 2, for application in a spatial context that also meets the needs of family 1, as described above.

- 1a. (To address issue no. 1) Retain stands of late-seral forests in the subalpine, montane, and lower montane communities; actively manage to promote their long-term sustainability; and manage young stands to develop late-seral characteristics. In the Southern Cascades and Upper Klamath ERUs, prescribed burns and understory thinning may be required to avoid loss of late-seral forests. In the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, Upper Snake and Snake Headwaters ERUs, it may be necessary to identify mid-seral forests in the lower montane community that could be brought to late-seral conditions because late-seral lower montane forests that can be mapped at the broad scale have been eliminated in these areas.
- 1b. (To address issue no. 1) As a short-term strategy, retain all large-diameter (>53 cm [21 in] d.b.h.) snags and large trees in the subalpine, montane, and lower montane communities, preferably in clumps, and provide opportunities for snag recruitment. As a long-term strategy, conduct mid-scale assessment to determine biophysical snag dynamics at a watershed scale and adjust the strategy by subbasin or groups of subbasins.
- 1c. (To address issue no. 1) Include family 2 conservation within a larger, ecosystem context that addresses management of primary cavity nesters and the small-mammal prey base for species within family 2. This includes maintenance of old-forest attributes such as coarse woody debris, fungi, and lichens.
2. (To address issue no. 2) Integrate the short-term strategy for conservation of current family 2 habitat with conservation of current family 1 habitat through mid-scale step-down assessment. Concurrently, develop a long-term strategy to repattern watersheds basin-wide to a mosaic of sustainable levels of family 1 and family 2 habitats.
3. (To address issue no. 3) Increase connectivity of disjunct habitat patches and prevent further reduction of large blocks of contiguous habitat. For martens and fishers, provide large contiguous areas of forested habitat at the home range scale. Notably, these species are generally not affected by forest openings less than about 120 m (390 ft) wide (Hargis and McCullough 1984, Koehler and Hornocker 1977), so large contiguous areas with small forest openings would also benefit the species with contrasting habitat needs: silver-haired bat, hoary bat, and great gray owl. For boreal owls, evaluate the links among subpopulations and use that information to identify areas that are highest priority for retention and restoration of habitat. This is of particular concern in the Northern Glaciated Mountains, Upper Clark Fork, and Lower Clark Fork ERUs, where reduction in the extent of source habitats has increased the isolation of remaining habitat patches.
4. (To address issue no. 4) Integrate a long-term strategy to repattern forest and forest-range landscape mosaics at the watershed scale through mid-scale step-down assessment. Develop patterns that consider issue no. 3 (fragmentation) in context of historical patterns as well as the biophysical succession-disturbance regimes.
5. (To address issue no. 5) Minimize or avoid road construction within late-seral forests. Obliterate or restrict use of roads after timber harvests and other management activities. Give special consideration to obliteration of roads that would help reduce poaching of caribou.
6. (To address issue no. 6) Continue a strategy of wildfire suppression in most managed forests while allowing stand-replacing wildfires to burn in wilderness areas,

areas of critical environmental concern (ACECs), and other natural process areas. Stand-replacing wildfires in such natural process areas are of particular benefit to black-backed and three-toed woodpeckers. In managed areas, use prescribed fire, timber harvest and thinning to change forest composition and structure to reduce risk of stand-replacement wildfires and loss of large emergent trees and overstory trees to benefit other species in family 2. Shift fire regimes to mixed fire behavior (as defined by Hann and others 1997), underburns, and creeping-irregular disturbance events through use of prescribed fire.

Family 3—Forest Mosaic Family

Family 3 is composed of groups 14 through 17 and consists of 6 species: the hermit warbler, pygmy shrew, wolverine, lynx, blue grouse (summer habitat only), and mountain quail (summer) (table 6). Ranges of these species are shown in figs. 39, 42, 45, 48, and 51, volume 2.

Source habitats and special habitat features—

Species within this family tend to be habitat generalists in montane forests; most species also use subalpine forests, lower montane forests, or riparian woodlands as source habitats (table 11). The blue grouse and mountain quail are the only species in this family that use upland shrublands, and during summer, the blue grouse also uses upland herblands. Source habitats generally include all structural stages.

Downed logs are a special habitat feature for the wolverine and lynx because they serve as potential resting and denning sites (vol. 3, appendix 1, table 2). Wolverines also have been found to use talus slopes as denning sites (Copeland 1996), and therefore talus is considered a special habitat feature for this species.

Special habitat features for the mountain quail are the shrub-herb understory in forest communities and shrub-herb riparian vegetation (vol. 3, appendix 1, table 2). Areas with abundant shrubs in the understory are used for cover as well as forage (Brennan and others 1987, Zwickel 1992). Riparian areas appear to be preferred, because mountain quail within the basin are primarily found within 100 to 200 m (328 to 656 ft) of a water source (Brennan 1989).

The blue grouse is considered a contrast species (vol. 3, appendix 1, table 2) because the species requires a juxtaposition of forest and nonforest vegetation structure to meet all aspects of its ecology (see “Glossary,” vol. 3, for definition of contrast species and related terms). Blue grouse nest on the ground but use trees for roosting and flush into trees when disturbed. Breeding areas are generally on the forest/shrub interface (Zwickel 1992).

Broad-scale changes in source habitats—Trends in source habitat extent differ across the basin for family 3, with neutral trends predominating. Within all watersheds having source habitats, 22 percent exhibited declining trends, 32 percent had increasing trends, and 46 percent were neutral (fig. 11). Six ERUs had increasing trends in >50 percent of watersheds, six had neutral trends, and only the Upper Clark Fork ERU had predominantly decreasing trends (table 12). Increasing trends were mostly in the south and central ERUs: the Southern Cascades, Upper Klamath, Northern Great Basin, Columbia Plateau, Blue Mountains, and Upper Snake ERUs (fig. 11, table 12).

Although the overall extent of source habitats for family 3 changed little since the historical period, there were notable changes in the extent of terrestrial community types that compose source habitat. Within the lower montane community, ecologically significant declines were projected basin-wide for early- and late-seral stages, but these were partially offset by ecologically significant increases in mid-seral lower montane forests (Hann and others 1997). There also were contrasting trends among the various structural stages of the subalpine community: ecologically significant decreases in late-seral multi-layer forests, and ecologically significant increases in late-seral single-layer and early-seral forests. Within the montane community, mid-seral structures exhibited ecologically significant increases throughout the basin, whereas there were declines in both early- and late-seral structures (Hann and others 1997). The Upper Clark Fork had declining trends in 71 percent of watersheds (table 12) because seven of nine communities with significantly declining trends decreased by more than 80 percent, and these declines were only partially offset by increases in mid-seral forests (Hann and others 1997).



Figure 11—Trend in source habitats for family 3 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

Primary causes for habitat trends and the associated ecological processes—Although forest habitats as a whole for the forest mosaic family did not show significant broad-scale change from historical to current periods, there were substantial changes in community structure and spatial distribution. Early- and mid-seral montane forests were influenced by cycling disturbance regimes that moved mid-seral to early-seral condition while early-seral forest succeeded to mid-seral condition. Because of these transitions, much of the current early-seral forest lacks the historical structure, which included large snags and large emergent trees that survived crown fires, clumps of upland trees that survived because of mixed fire behavior, narrow stringers of old-forest structure in riparian, and large down logs (Hann and others 1997, Hessburg and others 1999). In essence, timber harvest practices substantially simplified the fine-scale attributes of early-seral patches. In addition, harvested early-seral areas have more disturbed soil and are more heavily infested by exotic plants such as Canada thistle and spotted knapweed instead of native understory herbs and shrubs.

Because much of this change in forest structure resulted from management activity, the change can be correlated with road density. Mid-seral patches in areas of moderate to high road densities declined in densities of large trees, large snags, and large down logs, but increased in small tree density, small down wood, and litter-duff depths (Hann and others 1997, Hessburg and others 1999). In contrast, mid-seral patches in areas of low road densities still retained the large emergent tree, large snag, and large down log components but had similar trends of increased small-tree density, small down wood, and litter-duff depth. These changes in fine-scale components of mid-seral patches in proximity to roads were attributed to a complex combination of timber harvest, woodcutting, fire exclusion, blister rust mortality of western white pine and whitebark pine, and increased insect-disease tree mortality that resulted from harvest-induced changes in tree composition to more susceptible species (Hessburg and others 1999). Changes in areas of low road densities or unroaded areas were attributed primarily to fire exclusion, effects of blister rust mortality, and increased insect-disease mortality because of competition-induced stress from high small-tree densities.

Another significant transition from the historical to current period was the shift of fire-maintained upland herbland to mid-seral lower montane forests (1.3 percent basin-wide) (Hann and others 1997). The analysis of Hessburg and others (1999) and Hann and others (1997) indicated that the fire-maintained upland herbland was typically a savannah with scattered large ponderosa pine and Douglas-fir trees and snags. The shift of this type to relatively dense, stressed mid-seral ponderosa pine and Douglas-fir was attributed primarily to fire exclusion and excessive livestock grazing, which decreased the competitive ability of the native grasses.

A substantial spatial shift also occurred from historical to current periods in the distribution of habitats for family 3 (fig. 11). Watersheds with decreasing trends generally occurred to the north and east in a mosaic with watersheds that showed no change. The increases generally occurred to the south and west. In the North Cascades and Northern Glaciated Mountains ERUs, some watersheds with increasing trends were scattered in a mosaic with watersheds with neutral trends.

Early-seral lower montane and montane departure classes with less than the historical range of variability (HRV) minimum occurred in 79 and 44 percent of subbasins, respectively, whereas early-seral subalpine forests occurred above the HRV maximum in 56 percent of subbasins (Hann and others 1997). Mid-seral lower montane, montane, and subalpine communities had levels of subbasin departure greater than the historical maximum for 58, 57, and 30 percent, respectively. Late-seral lower montane, montane, and subalpine had levels of subbasin departure lower than the historical minimum for 78, 59, and 63 percent, respectively.

Of particular pertinence to habitats for family 3 was the fact that departure of landscape mosaic pattern was high in 8 of the 13 ERUs for the current period compared to the historical period (Hann and others 1997). Broad-scale mosaic patterns were moderately fragmented in 5 of the 13 ERUs, whereas moderately simplified in 7 of 13 ERUs. The implication for family 3 forest habitat generalists is that fragmented landscapes could lack adequate connectivity, whereas simplified landscapes could lack important structural components. This trend is supported by the terrestrial community departures discussed earlier, which indicate that subbasins typically have less diversity and evenness (simplified) of communities than historically.

The patterns of some subbasins are more fragmented (more and smaller patches), whereas other subbasins are more homogeneous. The mid-scale assessment of Hessburg and others (1999) confirmed a similar trend at the watershed scale.

Family 3 may be one of the best families to use as an indication of context for forests of the basin. The lack of overall change in amount of forests could indicate that the general decline of some species in this family may not be habitat-related. Some members of the family may have declined, in part, because of hunting, trapping, or other negative interactions with humans. It is also plausible, however, that the population declines are partially a result of change in landscape pattern and simplification of several forest attributes that have occurred, and continue to occur across the basin, among subbasins, and within subbasins, watersheds, and terrestrial communities.

Other factors affecting the family—Trapping can be a significant source of mortality for wolverine (Banci 1994) and lynx (Bailey and others 1986, Carbyn and Patriquin 1983, Mech 1980, Nellis and others 1972, Parker and others 1983, Ward and Krebs 1985). Currently in the basin, wolverine can be trapped in Montana (Banci 1994). Increased roads have provided trappers greater access to lynx and wolverine populations.

Other forms of human disturbance such as heliskiing, snowmobiles, backcountry skiing, logging, hunting, and summer recreation have been suggested as having potentially negative effects on wolverines and lynx, but the effects are not well documented (Copeland 1996, Hornocker and Hash 1981, ICBEMP 1996c, Koehler and Brittell 1990). Most of these recreational activities occur, however, in high-elevation areas used as denning sites by wolverine, and production of young at denning sites is considered a primary factor limiting wolverine population growth (Copeland 1996, Magoun and Copeland 1998).

Low-elevation riparian shrub habitat is of primary importance to quail, especially during severe winters. Hydroelectric impoundments along the Columbia River and its tributaries have eliminated thousands of acres of habitat by flooding low-elevation, primarily winter, habitat for mountain quail (Brennan 1990).

Other factors that have negatively impacted riparian shrublands are historical livestock grazing practices, agriculture, excessive recreational use, encroachment of exotic plants, and road construction (Brennan 1990, Murray 1938, Vogel and Reese 1995). Basin-wide analysis of riparian vegetation found significant changes, including widespread declines in riparian shrublands (Lee and others 1997, Quigley and others 1996). Because of the scale of our analysis and the fine-scale nature of riparian shrubland habitats, the results of our analysis likely do not reveal the true loss in this important habitat component for mountain quail.

Issues and strategies for conservation—At the broad-scale, source habitats for family 3 have not declined to the extent observed for families 1 and 2 because the species in this family are capable of using a wider variety of cover types and structural stages than the species in the two old-forest families. Conservation strategies proposed for families 1 and 2 generally will benefit broad-scale habitats for family 3. There are additional issues and strategies relative to quality of habitat and effects of changes in landscape pattern and simplification of forests. The following issues and strategies are provided:

Issues—

1. Potentially negative impacts of human disturbance on wolverine and lynx populations.
2. Loss of riparian shrubland for mountain quail at finer scales than this broad-scale assessment.
3. Changes in landscape pattern and simplification of forests across subbasins, within subbasins and watersheds, and within terrestrial communities.

Strategies—The following strategies could be considered to address issues related to species belonging to family 3:

- 1a. (To address issue no. 1) Provide large areas with low road density and minimal human disturbance for wolverine and lynx, especially where populations are known to occur. Manage human activities and road access to minimize human disturbance in areas of known populations.

- 1b. (To address issue no. 1) Manage wolverine and lynx in a metapopulation context, and provide adequate links among existing populations. Areas supporting dispersal likely would not require the same habitat attributes needed to support self-sustaining populations (Banci 1994).
2. (To address issue no. 2) Maintain and restore riparian shrublands through restoration of historical hydrologic regimes where feasible, through control of livestock grazing, and through better management of roads and recreation.
3. (To address issue no. 3) Conduct mid-scale step-down assessment of current conditions relative to landscape departure patterns of succession-disturbance regimes. Focus short-term restoration of watersheds on those that depart greatly from succession-disturbance regimes, that do not contain susceptible populations of species of high conservation concern, and that are at high risk of loss of biophysical capability. In such watersheds, continue suppression of stand-replacing, high-severity wildfires, and initiate prescribed fire appropriate to the biophysical succession-disturbance regime and timed to protect biophysical capability.

Family 4—Early-Seral Montane and Lower Montane Family

This family has one member, the lazuli bunting (group 18). Its range is shown in vol. 2, figure 54.

Source habitat and special habitat features—The lazuli bunting was assigned a separate family because of its unique dependence on early-seral, shrub-dominated conditions in forested environments. Source habitats for the family were defined as the stand initiation stages of subalpine, montane, lower montane, and riparian woodland communities (table 11; vol. 3, appendix 1, table 1). Most cover types that serve as source habitat are in the montane community.

Broad-scale changes in source habitats—Source habitats declined in 60 percent of watersheds basin-wide between the historical and current periods (fig. 12). Seven percent of watersheds had neutral trends, and 33 percent had increasing trends. At least 50 percent of watersheds had decreasing trends in eight ERUs: Upper Klamath, Northern Great Basin, Columbia Plateau, Blue Mountains, Northern

Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Upper Snake (table 12). Habitats increased in at least 50 percent of watersheds in the Northern Cascades, Snake Headwaters, and Central Idaho Mountains. Trends were mixed in the Southern Cascades and Owyhee Uplands ERUs.

Ecologically significant increases occurred in early-seral subalpine forests in all three ERUs with positive trends, and early-seral montane forests increased in two of them (Hann and others 1997). Within the eight ERUs that showed overall declines in source habitats, early-seral lower montane forests underwent ecologically significant declines in all of them, and early-seral montane forests declined in five of them.

Primary causes for habitat trends and the associated ecological processes—Fire suppression and the frequency and rate of timber harvest are the main causes for the widespread, strong decline in early-seral source habitats for family 4. In particular, Hann and others (1997) found a substantial basin-wide decline of early-seral lower montane forests (-77 percent) and a slight decline in early-seral montane (-8 percent). In addition, Hann and others (1997) found high levels of HRV departure for early-seral habitats in lower montane and montane forests, reflecting a combination of intensive timber harvest, fire suppression, roading, and invasion of exotic plants. This high HRV departure in early-seral habitats was associated with a substantial reduction in patch size and habitat quality (Hessburg and others 1999).

Spatial trends in source habitats for lazuli bunting resulted from variable types and intensities of timber harvest concurrent with fire suppression across the basin. Recent timber harvest has increased areas of the stand initiation stage in some areas, whereas fire suppression has tended to decrease area of the stand initiation stage to a much larger extent (Hann and others 1997).

Trends for family 4 were spatially disjunct (fig. 12). Increases occurred in the Northern Cascades, Central Idaho Mountains, and Snake Headwaters in response to wildfires and some timber harvest. Decreases occurred throughout much of the rest of the basin in response to the overwhelming effects of fire exclusion, with few watersheds showing a neutral response.



Figure 12—Trend in source habitats for family 4 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

In general, declines occurred in the more mesic environments with milder temperatures and higher productivity. By contrast, increases occurred in environments with cooler average temperatures and lower productivity.

Of particular concern relative to the early-seral structure is the finding of Hann and others (1997) and Hessburg and others (1999) that current conditions do not resemble historical conditions at a patch scale. Early-seral communities historically were found to have scattered large tree emergents that survived stand-replacing and mixed-fire events as well as large- and medium-size snags. Current early-seral communities commonly are now devoid of large tree emergents and snags, have comparatively high levels of disturbed soil, and contain exotic weeds. In addition, the commonly used 5-year regeneration objective of accelerating the regeneration process by planting may have shortened the time that stands remain in the early-seral stage (Hann and others 1997). Planting in postfire habitats also shortens the duration of the stand-initiation stage. The practice of planting also reduces the abundance of herb, forb, and shrub structure from early-seral stands.

Other factors affecting the family—Hutto (1995) found that lazuli buntings demonstrated a strong positive response to early successional burned forests resulting from stand-replacing fires in western Montana and northern Wyoming. In addition, lazuli buntings are Neotropical migrants and thus are affected by factors outside of their breeding habitat within the basin.

Issues and strategies for conservation—The primary issues and strategies for family 4 relate to declines in source habitats.

Issues—

1. Reduction in early-seral terrestrial communities.
2. Altered frequency of stand-replacement fires.
3. Reduction of shrubs in early-seral vegetation types.

Strategies—The following strategies could be considered to address issues related to species belonging to family 4. Four broad-scale strategies would be effective in improving habitat for lazuli buntings and other postfire-dependant species:

1. (To address issues no. 1 and no. 2) Restore fire as an ecological process in the montane and lower montane community groups.
2. (To address issues no. 1 and no. 2) Implement silvicultural strategies and practices that result in composition and structure of vegetation that mimic effects of historical fire regimes.
3. (To address issue no. 3) Allow natural development of early-seral and postfire habitats to increase the representation of early-seral shrubs where appropriate for the biophysical environment. Change reforestation goals to allow for development and maintenance of postfire habitats that are dominated by shrubs and herbs.

Family 5—Forest and Range Mosaic Family

Family 5 consists of groups 19, 20, 21, and 22, which include the gray wolf, grizzly bear, mountain goat, long-eared owl, and two subspecies of bighorn sheep (table 6). Ranges of these species are shown in figures 57, 60, 63, and 66, volume 2.

Source habitats and special habitat features—

Species in family 5 use a broad range of forest, woodlands, and rangelands as source habitats (table 11; vol. 3, appendix 1, table 1). Source habitats include all terrestrial community groups except for exotics and agriculture. The Rocky Mountain and California bighorn sheep differ from other family members in that they do not use habitats in the montane, lower montane, and upland woodland community groups. The long-eared owl also does not use alpine or subalpine community groups as source habitats.

The long-eared owl is considered a contrast species, requiring a juxtaposition of contrasting vegetation structures to meet all life history needs (vol. 3, appendix 1, table 2). Where forests are adjacent to open areas, trees are typically used for nest sites. Where forests are not present, nests are placed in tall shrubs (Holt 1997). Special habitat features for the mountain goat and both subspecies of bighorn sheep are cliffs, talus, and shrub/herb riparian vegetation (vol. 3, appendix 1, table 2). Cliffs provide important escape terrain, and shrub/herb riparian vegetation provides high-quality forage for these mountain-dwelling herbivores. No special habitat features were identified for



Figure 13—Trend in source habitats for family 5 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

the gray wolf or grizzly bear, although the grizzly bear also seeks talus areas and shrub/herb riparian vegetation for high-quality forage during summer.

Broad-scale changes in source habitats—Basin-wide, 51 percent of watersheds had stable trends in source habitats, 35 percent had decreasing trends, and 14 percent had increasing trends (fig. 13). The greatest declines were in the Lower Clark Fork ERU, where 82 percent of watersheds showed declines (table 12). Other ERUs with decreasing trends in >50 percent of watersheds were the northern half of the Columbia Plateau, Upper Clark Fork, and Upper Snake ERUs. Increasing trends for family 5 were mostly in the Upper Klamath and Central Idaho Mountains ERUs and in portions of the Northern Glaciated Mountains ERU (fig. 13), but the average trends in all three ERUs was neutral (table 12).

Primary causes for habitat trends and the associated ecological processes—Trends were spatially disjunct and correlated with human-caused effects. Declines occurred in correlation with invasion of exotic plants and agriculture and urban development in environments with generally longer growing seasons and more productive soils. Neutral areas occurred primarily in the rangelands, dry forest, or cold forest where productivity is lower and thus where less agricultural and urban development occur. Cover type and structural stage transitions in the montane and lower montane community groups resulted in no net change in source habitats for family 5. For example, extensive declines in old-forest structural stages of all forest cover types have occurred (Hann and others 1997), but these losses have been offset by increases in mid-seral stages that also serve as source habitats for the gray wolf, grizzly bear, long-eared owl, and to a lesser extent, the mountain goat. Bighorn sheep do not use most structural stages of forest cover types, so the structural transitions that occurred did not affect their source habitat. Ecologically significant losses of all structural stages occurred in western white pine, whitebark pine, western larch, and limber pine (Hann and others 1997).

Within nonforest terrestrial communities, upland herbland and upland shrubland have strongly declined, whereas three new terrestrial communities, urban, agriculture, and exotic herbland, have emerged since the historical period (Hann and others 1997), none of which serves as source habitat for this family.

Source habitat declines in the Columbia Plateau and Upper Snake ERUs were attributed primarily to the conversion of upland shrubland and upland herbland to agriculture (Hann and others 1997). Currently, 42 percent of the Columbia Plateau and 36 percent of the Upper Snake ERU are now in agriculture. Similar transitions occurred in the Lower and Upper Clark Fork ERUs, although the areal extent of the transitions was less.

Of particular relevance to habitats for family 5 is the fact that forest and range landscape patterns have changed extensively across the basin (Hann and others 1997, Hessburg and others 1999). The spatial redistribution of forest and range terrestrial communities has resulted in 80 percent of all subbasins being below the minimum for HRV for one or more forest or range terrestrial communities. Only 2 percent of landscape patterns were projected to have patterns consistent with the biophysical succession-disturbance regime across all ownership and 5 percent on FS- and BLM-administered public lands. Forest landscape patterns have highly fragmented mosaics but simplified patch composition and structure in roaded areas, whereas unroaded areas were more simplified in both mosaic and patch composition and structure. Rangelands were more simplified in both mosaics (except in areas of exotic plant invasion) and patch composition and structure. Forest-rangeland landscapes responded somewhat similar to forest landscapes but with higher diversity of types. These changes in landscape patterns may have substantially changed foraging and other life functions for species in family 5, which may have contributed to the substantial range contractions that have occurred for all species in this family (vol. 2, figs. 57, 60, and 66) with the exception of the long-eared owl (fig. 63, vol. 2).

Other factors affecting the family—Human disturbance is a primary factor affecting most species in family 5. Most mortalities of the gray wolf and grizzly bear are due to humans. About 84 percent of all known mortalities of wolves on the Montana-British Columbia-Alberta border were human-caused (Pletscher and others 1997), and in the northern Rockies, 85 to 94 percent of all deaths (1974-96) of marked grizzly bears >1 year old were due to humans (Mattson and others 1996b). Additionally, human activities result in the displacement of wolves and grizzly bears from otherwise high-quality habitat (Mace and

others 1996, Mladenoff and others 1995), and human developments cause habitat fragmentation (Noss and others 1996).

Mountain goats and bighorn sheep are not subjected to the same negative attitudes as wolves and grizzly bears, but they are nevertheless highly susceptible to hunting, both legal and illegal (Johnson 1983, Matthews and Coggins 1994). Also, human activities such as recreational hiking, road construction, timber harvesting, and mining can cause physiological stress and displacement from habitats (Chadwick 1972, Hamilton and others 1982, Hicks and Elder 1979, Johnson 1983, Joslin 1986, MacArthur and others 1982). Of all species in family 5, the long-eared owl seems to be the least affected by direct human disturbances.

All species in family 5 except for the long-eared owl are considered road-sensitive because the negative impacts from human activities often are increased where roads are present. A disproportionate number of human-caused mortalities occur near roads, both for wolves (Mech 1970) and grizzly bears (Mattson and others 1996b). Roads, particularly highways, have been documented as a source of mortality for mountain goats through vehicle collisions (Singer 1978). Also, roads increase hunter access for both mountain goat and bighorn sheep herds (Johnson 1983).

The condition of habitats for bighorns and mountain goats has been altered over the last century because of changes in historical fire regimes. Fire suppression has resulted in an increase in the density of trees in formerly open stands, reducing forage quantity, forage quality, and openness, all of which make such stands largely unsuitable for bighorn sheep and mountain goat. For the Rocky Mountain bighorn, fire-suppressed stands have created barriers between historical winter and summer range, thereby preventing occupancy of the total range even though each isolated range is currently suitable (Wakelyn 1987).

Riparian vegetation has declined in extent basin-wide, because of disruption of hydrologic regimes from dams, water diversions, road construction, grazing, and increased recreational use along stream courses (Lee and others 1997, USDA Forest Service 1996). Loss of riparian vegetation has degraded important foraging areas for bighorn sheep, mountain goats, and grizzly bears and potential nesting habitat for the long-eared owl.

Bighorn sheep are highly susceptible to pneumonia after exposure to bacteria (*Pasteurella* spp.), viruses (*Parainfluenza* type-3), lungworm, and stress agents (Foreyt 1994, Wishart 1978). Major reductions or total extirpation of bighorn herds from pneumonia outbreaks are well-documented (Cassirer and others 1996, Coggins 1988, Onderka and Wishart 1984, Spraker and others 1984). Abundant circumstantial evidence (Coggins 1988, Foreyt and Jessup 1982, Martin and others 1996) and recent direct evidence exist (Foreyt 1994; Rudolph and others, in prep.) that domestic and exotic sheep are the source of nonendemic bacteria and viruses predisposing bighorn sheep to pneumonia. Disease transmission from domestic animals is not a major threat to other species in family 5. It is mentioned here, however, because it is currently the most significant factor affecting bighorn sheep conservation.

Issues and strategies for conservation—The primary issues for family 5 relate to direct and indirect human impacts on populations and habitat quality. These issues areas are as follows:

Issues—

1. Habitat fragmentation (poor juxtaposition of seasonal ranges as well as isolation of small populations) because of agricultural, industrial, and recreational development.
2. Displacement from suitable habitats because of human activities and the facilitation of human activities by roads.
3. Degradation and loss of native upland shrublands, upland grasslands, riparian shrublands, and riparian woodlands.
4. Changes in landscape patterns of source habitats and reduction in forage quantity and quality for mountain goats and bighorn sheep because of changes in fire regimes.
5. Disease transmission potential between domestic sheep and bighorn sheep.
6. Excessive bear and wolf mortality from conflicts with humans.

7. Habitat fragmentation or simplification across the basin among subbasins, watershed scale landscape mosaics, and at patch composition and structure.

Strategies—The following strategies could be considered to address issues related to species belonging to family 5. These strategies are appropriate for all areas of the basin with current populations of one or more of the species in family 5, or with suitable, unoccupied habitat where recovery of these species has been identified as a management goal.

1. (To address issue no. 1) Seek opportunities to increase habitat links between isolated populations and seasonal foraging areas caused by human land uses. For wolves and grizzly bears, design interregional habitat connectivity across all ERUs where populations are currently present (Northern Cascades, Northern Glaciated Mountains, Upper Clark Fork, Lower Clark Fork, Central Idaho Mountains, and Snake Headwaters).
- 2a. (To address issue no. 2) Reduce human activities near important seasonal foraging areas of any species in family 5 and around known wolf dens and lambing and kidding areas of bighorn sheep and mountain goats.
- 2b. (To address issue no. 2) Develop a policy for road construction, maintenance, and obliteration on public lands to reduce human access to specific areas considered key to the conservation of species in family 5.
- 3a. (To address issue no. 3) Increase quality and amount of riparian shrublands and woodlands through restoration of hydrologic flows, vegetation restoration, road management, and control of grazing and recreational activities.
- 3b. (To address issue no. 3) Maintain and restore native upland shrublands and upland grasslands, particularly in the northern half of the Columbia Plateau, Lower Clark Fork, Upper Snake, and Snake Headwaters ERUs.
4. (To address issue no. 4) For mountain goats and bighorn sheep, restore habitat links between summer and winter range and access to escape cover that have been lost because of changes in historical fire regimes. Restore quality and quantity of forage

where succession has caused substantial reductions. Implement use of prescribed fire to reestablish inherent fire regime-vegetation patterns.

5. (To address issue no. 5) Actively control the potential for disease transmission between bighorns and domestic livestock.
6. (To address issue no. 6) Reduce the prevalence of conflict situations and human-caused mortalities of bears and wolves.
7. (To address issue no. 7) Conduct mid-scale assessment as part of multiscale step-down implementation to identify risks and opportunities for restoration among subbasins, repattern priority watersheds based on the biophysical succession-disturbance patterns, and conserve or restore patch composition and structure to mimic that appropriate to the succession-disturbance regime.

Family 6—Forest, Woodland, and Montane Shrub Family

This family consists of groups 23, 24, and 25 (table 6). Species in these groups are the sharptail snake, California mountain kingsnake, northern goshawk (winter), rufous hummingbird, broad-tailed hummingbird, and black-chinned hummingbird. The ranges of these species are generally widespread throughout the basin except for the two snake species, which have small, isolated ranges (vol. 2, figs. 69, 72, 75).

Source habitats and special habitat features—

Source habitats of the six species in this family consist of montane and lower montane forests, riparian and upland woodlands, chokecherry-serviceberry-rose, mountain mahogany, and riparian shrublands (table 11; vol. 3, appendix 1, table 1). Source habitats for family 6 occur in all 13 ERUs. However, habitat for most species was never common in the Northern Great Basin, Columbia Plateau, Owyhee Uplands, or Upper Snake (vol. 2, figs. 70, 73, and 76).

Special habitat features include nectar-producing flowers for the hummingbird species and logs and talus for the snake species (vol. 3, appendix 1, table 2).

Broad-scale changes in source habitats—Changes in source habitats were variable across the basin. Source habitats had decreasing trends in 45 percent of the



Figure 14—Trend in source habitats for family 6 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

watersheds in the basin and increasing trends in 37 percent (fig. 14). The Blue Mountains, Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork had an overall decreasing trend, whereas the Snake Headwaters and Central Idaho Mountains had overall neutral trends (table 12). The four primarily nonforested ERUs—Northern Great Basin, Columbia Plateau, Owyhee Uplands, and Upper Snake—as well as the Upper Klamath have little habitat overall but showed increasing trends.

Reasons for increases and decreases were variable, but declines were associated with reductions in late-seral and early-seral lower montane and montane forests, riparian woodlands, and riparian shrublands (Hann and others 1997). Increases were associated with transitions to mid-seral coniferous forest (primarily managed young forests) and to increases in the upland woodland community group. Large increases in juniper/sagebrush in all or parts of the Upper Klamath, Northern Great Basin, Columbia Plateau, Blue Mountains, Upper Snake, and Snake Headwaters ERUs contributed to much of the increases shown in figure 14.

Primary causes for habitat trends and the associated ecological processes—Fire exclusion, heavy livestock grazing, intensive timber harvest, and road-building have contributed to changes in areal extent and quality of source habitats for family 6. Trends in conditions of shrubs, logs, talus and flowers are not available at the broad scale, and these special habitat features are particularly important to the life histories of many species in family 6. Activities that may negatively affect these special habitat features include fire exclusion, timber harvest, road construction and maintenance, livestock grazing, and mining. Fire exclusion may impact flower abundance by increasing forest canopy closure, thereby reducing the amount of herbaceous understory and an associated decline in fire-adapted forbs. Heavy grazing also has reduced the density of understory plants used as a food source (nectar) by hummingbirds (Saab and Rich 1997).

At a broad scale, an ecologically significant decline occurred in early-seral (-77 percent) and late-seral single-layer lower montane (-80 percent), and a slight decline in early-seral montane (-8 percent), which would be the major shrub-, flowering forb-, and grass-producing forest stages of family 6 source habitats. Almost all subbasins of the basin currently are less

than the HRV minimum for these stages. These habitats transitioned primarily to mid-seral lower montane and montane stages. Even in the historical condition, the mid-seral stages have higher density of tree overstory and thus have less shrub and herb understory diversity than the early-seral or late-seral single-layer stages. In the current condition, however, the areas in mid-seral were found to have even less shrub and understory diversity than historically because of fire exclusion. Consequently, fine-scale attributes for species in family 6, such as shrubs, forbs, and down logs, likely have been reduced further in abundance in mid-seral habitats compared to historical conditions.

In addition, an ecologically significant decline occurred in the upland shrubland terrestrial community (-31 percent) from historical to current periods. Most of the upland shrub that declined was of the sagebrush-steppe type, which for nonpublic lands was converted primarily to agriculture. On public lands, about a third of the decline transitioned to upland woodland (juniper/sagebrush); this was considered an increase in source habitat for family 6 but would be of lower habitat quality for those species associated with herbaceous shrubs than the mountain shrubs of the lower montane and montane forests.

Most species in family 6 seem to be adapted to forest openings, down logs, shrubs, and flowering forbs. This type of condition would be found in correlation with frequent underburn or mixed-fire events. Current shrub and herbaceous (forb and graminoid) diversity and productivity have declined considerably as a result of fire exclusion, increased tree density, and excessive livestock grazing. In addition, a basin-wide decline occurred in mid-scale detectable riparian shrubland correlated with excessive livestock grazing (Lee and others 1997). Large down logs have declined in areas accessible to roads as a result of woodcutting and timber harvest of large trees, which are the recruitment source for logs.

Of additional pertinence to source habitats for family 6 is the fact that landscape patterns at subbasins and watershed scales changed substantially from historical to current, with only 2 percent estimated to retain their native pattern according to Hann and others (1997) and Hessburg and others (1999). These authors found that most ERUs exhibited high levels of departure from the historical biophysical succession-disturbance regimes and simplification of many of fine-scale attributes important to species in family 6.

Trends of watershed change for the forest, woodland, and montane shrub habitats for family 6 were spatially disjunct (fig. 14). Decreases generally occurred in the northern and eastern portions of the basin, whereas increases and neutral changes were in a mosaic in the central and southern portions of the basin. These patterns resulted from the combination of fire exclusion across all forests and rangelands of the basin, and the timber harvest practices that occurred in the northern portion of the basin. In general, the increases have occurred in environments that are warmer, drier, and less productive, and declines have occurred in more mesic habitats.

Other factors affecting the family—Humans have had a direct effect on all species of snakes through collection, harassment, accidental mortalities, as well as intentional killing because of fear and hate (Brown and others 1995). Also of particular concern with these snake species is population isolation: both the California mountain kingsnake and sharptail snake have small, isolated distributions in the basin (vol. 2, fig 72).

Little is known about the population dynamics of the goshawk (Squires and Reynolds 1997). Several studies, however, have documented a positive relation between prey abundance and nest success (Doyle and Smith 1994, Linden and Wikman 1983, Ward and Kennedy 1996), which presumably also exists between prey abundance and goshawk survival during winter (recall that source habitats for goshawk in family 6 are winter habitat only). Habitat components associated with high prey abundance for goshawk—such as snags, down logs, herbaceous understories, and interspersed of different structural stages—may have been negatively affected by past management activities.

The three hummingbird species are Neotropical migrants. The availability of habitats used during migration, as well as their winter habitat, are critical components, and information on the abundance of or trends in these habitats is lacking.

Issues and strategies for conservation—Because species in family 6 use various cover types and structural stages, issues and strategies for the species are directed at maintaining diversity of vegetation conditions, with emphasis on restoration of habitats and vegetative components that have declined.

Issues—

1. Decline in the abundance of late- and early-seral forests.
2. Likely loss of forest openings with herbaceous understories that provide for small-mammal prey base (for goshawk), and flowers (for hummingbird species).
3. Overall loss of riparian woodlands and herbaceous shrublands, including loss of herbaceous shrubs within these communities.
4. Loss of habitat connectivity particularly for the sharptail snake and California mountain kingsnake.
5. Negative effects of human disturbance to the sharptail snake and California mountain kingsnake.
6. Decline in snags and logs and other important structural components used by sharptail snake, California mountain kingsnake, and the prey of goshawk.
7. Broad-scale changes in landscape patterns in combination with cumulative effects of simplification of fine-scale environmental factors at the ERU, subbasin, watershed, and patch scales (based on results of Hann and others [1997] and Hessburg and others [1999]).

Strategies—The following strategies could be considered to address issues related to species belonging to family 6:

1. (In support of issues no. 1 and no. 2) Enhance landscape diversity by increasing the mix of early- and late-seral stages, particularly in ponderosa pine, western larch, and western white pine types. Increase late-seral forests in the Southern Cascades, Columbia Plateau, Blue Mountains, Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork ERUs, where declines have been strongest. Increase early-seral forests in the Columbia Plateau, Northern Glaciated Mountains, and Lower Clark Fork ERUs in response to strong declines.
2. (In support of issues no. 1 and no. 2) Use prescribed fire and understory thinning to increase vegetative diversity. Several of the species in this

family depend on forest openings and understory shrubs, both of which were maintained historically through natural fire regimes.

3. (In support of issue no. 3) Seek opportunities to improve connectivity among isolated populations of the sharptail snake and California mountain kingsnake.
4. (In support of issue no. 7) Conduct mid-scale step-down assessment of current conditions relative to landscape patterns of succession-disturbance regimes. Focus short-term restoration of watersheds on those that are in high departure, do not contain susceptible populations of species of high conservation concern and are at high risk of loss of biophysical capability. Continue suppression of stand-replacing, high-severity wildfires, and initiate prescribed fire appropriate to the biophysical succession-disturbance regime and timed to protect biophysical capability.

Family 7—Forest, Woodland, and Sagebrush Family

Groups 26, 27, and 28 compose family 7. These three groups include the pine siskin and eight species of bats (table 10). Ranges of these species are shown in figures 78, 81, and 84, volume 2.

Source habitats and special habitat features—

Family 7 members use a complex pattern of forest, woodlands, and sagebrush cover types (table 11; vol. 3, appendix 1, table 1). Although the species in family 7 use a broad range of cover types and structural stages as source habitats, all but the pine siskin have special requirements for nesting or roosting (vol. 3, appendix 1, table 2). The bat species use cliffs, caves, mines, and buildings for day roosts and hibernacula (Manning and Knox-Jones 1989, Nagorsen and Brigham 1993). The pallid bat, long-eared myotis, fringed myotis, and long-legged myotis also use large-diameter (>53 cm [21 in]) trees and snags with exfoliating bark for maternity roosts and day roosts (Nagorsen and Brigham 1993, Ormsbee and McComb 1998, Rabe and others 1998).

Suitable roosting structures often limit bat distribution and population size (Humphrey 1975, Nagorsen and Brigham 1993, Perkins and Peterson 1997). For example, the distribution of Townsend's big-eared bat is

closely tied to the presence of caves and cavelike structures because they roost in large colonies and require a ceilinglike substrate for hanging (Idaho State Conservation Effort 1995, Nagorsen and Brigham 1993). The spotted bat also appears limited in roost site selection, with all roosts reported in crevices of high cliffs (Nagorsen and Brigham 1993, Sarell and McGuinness 1993, Wai-Ping and Fenton 1989). Snag-roosting bats require specific conditions usually provided by exfoliating bark or large cavities, and must shift their use to other snags when snag decomposition changes these conditions. Rabe and others (1998) suggest that snag-roosting bats may require higher densities of snags than cavity-nesting birds, because the stage at which snags are suitable for bat roosts is extremely short-lived, requiring the use of several snags over the course of a lifetime of a bat.

Shrub/herb riparian areas are a special habitat feature for two members of family 7, the Yuma myotis and long-eared myotis. The Yuma myotis specializes in foraging over water, where it eats midges and emergent aquatic insects (Whitaker and others 1977). The long-eared myotis concentrates most of its foraging in riparian areas, where it is a hover-gleaner (Barclay 1991, Nagorsen and Brigham 1993). Although shrub/herb riparian areas are not considered a requirement for the other bat species in this family, all use riparian areas for foraging because of high insect density.

Broad-scale changes in source habitats—Trends in source habitats were mixed: 47 percent of the watersheds basin-wide had neutral trends; 21 percent had increasing trends, and 32 percent had declining trends (fig. 15). Watersheds with declining trends were concentrated in the Lower Clark Fork and Upper Snake ERUs, and in the northern half of the Columbia Plateau ERU (fig. 15, table 12). The only ERU with increasing trends in more than 50 percent of its watersheds was the Upper Klamath.

Primary causes for habitat trends and the associated ecological processes—Stable trends in broad-scale source habitats throughout much of the basin reflect the wide range of cover types and nearly all structural stages of forests used as source habitats by species in family 7. The basin has experienced dramatic declines in old-forest structural stages of all forest cover types (Hann and others 1997), but for family 7, these losses have been offset by increases in mid-seral stages that



Figure 15—Trend in source habitats for family 7 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

also serve as source habitats. Populations of this family, however, likely could be in decline across their range because of basin-wide changes in landscape patterns and simplification of patch composition and structure (per results of Hann and others [1997] and Hessburg and others [1997]).

Declines in source habitats in the Lower Clark Fork were associated with the broad-scale transition of upland woodland to upland herbland (Hann and others 1997), the latter being a terrestrial community group that does not provide source habitat for family 7. In both the Upper Snake and Columbia Plateau ERUs, source habitat declines were attributed primarily to the conversion of upland shrubland to agriculture. Currently, 36 percent of the Upper Snake ERU and 23 percent of the Columbia Plateau are now in agriculture. Not all species in family 7 are affected by these declines because some of these species either do not occur in these ERUs or do not use upland shrubland as source habitats. The species most affected are long-eared myotis, Yuma myotis, small-footed myotis, Townsend's big-eared bat, and spotted bat.

Increasing trends in most watersheds within the Upper Klamath ERU were primarily due to the transition of upland herbland to several forest community groups that serve as source habitats. These include both mid- and late-seral lower montane and upland woodland terrestrial community types (Hann and others 1997). The transition of upland herbland to lower montane was also responsible for increasing trends in other ERUs, particularly in the central and southeastern areas of the basin.

In contrast to most other families, the mosaic of increasing, decreasing, and neutral trends was not highly disjunct spatially (see fig. 15). There was slight correlation of neutral trends with range landscape patterns and dry forest. Decreasing trends were somewhat correlated with the northerly and eastern portions of the basin, whereas increasing trends were scattered.

Other factors affecting the family—The bat species in family 7 are sensitive to human disturbance of roost sites and loss of roost sites. The most straightforward source of impact is destruction of the structure, i.e., loss of snags through timber harvests, and removal of old buildings and bridges or closure of mines and

caves for safety reasons (Perlmeter 1995, Pierson and others 1991). The second source of impact is disturbance of roosting bats, primarily by recreational activities in or near caves, but also from mining, road construction, and any other activities near roosts (Pierson and others 1991). During winter, the transition from torpor requires a large caloric output, and repeated disturbances can drain the energy reserves of bats and lead to starvation (Nagorsen and Brigham 1993). The third source of impacts at roost sites is purposeful killing of roosting bats.

Roads indirectly affect bat species by increasing human access to roost sites. Caves have become more accessible, increasing the amount of human visitation and potential harassment of bats. The presence of roads also increases the likelihood that snags will be cut for fuelwood (Hann and others 1997).

Riparian vegetation has declined in extent basin-wide, because of disruption of hydrologic regimes from dams and water diversions, road construction, grazing, and increased recreational use along stream courses (Lee and others 1997, USDA Forest Service 1996). Loss and degradation of riparian vegetation likely has reduced the diversity of insect prey for bats. Moreover, the loss of riparian woodlands has reduced the availability of sites for day and nursery roosts. Perkins and Peterson (1997) attributed the low detection of bats in the Owyhee Mountains to the lack of suitable roosts, particularly in riparian areas.

Pine siskin foraging behavior, geographic location, and population levels are highly influenced by the combination of current population level and food availability: an abundance of seeds will cause the population to expand, and if the next year's crop is unable to support the expanded population, the birds will move elsewhere (Bock and Lepthien 1976).

Issues and strategies for conservation—Because the species in family 7 are habitat generalists, changes that have occurred in terrestrial community groups since the historical period have resulted in few substantial changes in the extent of source habitats. The primary issues for family 7 relate to human impacts on populations and on special habitat features needed for roosting and foraging. These issues include the following:

Issues—

1. Loss of potential roost sites because of mine closures, destruction of abandoned buildings, snag removal, deliberate fumigation of buildings, and levels of human activity that cause roost abandonment.
2. Excessive disturbance of roosting bats because of human activities and roads as a facilitator of such activities.
3. Degradation and loss of native riparian vegetation.

Strategies—The following strategies could be considered to address issues related to the bat species in family 7. These strategies are appropriate for all areas of the basin. Strategies for pine siskin populations have not been formulated because the causes for apparent population declines at the continental scale are unknown.

1. (To address issue no. 1) Protect all known roost sites (nurseries, day roosts, and hibernacula) and restore useability of historical roosts where feasible. Actively manage for the retention and recruitment of large-diameter (>53 cm [21 in]) snags in all forest cover types and structural stages.
2. (To address issue no. 2) Reduce levels of human activities around known bat roosts through road management, signs, public education, and bat gates.
3. (To address issue no. 3) Maintain and improve the condition of riparian vegetation for bat foraging areas.

Family 8—Rangeland and Early- and Late-Seral Forest Family

The western bluebird (group 29) is the sole member of this family. This species was placed in its own family because its source habitats are a unique combination of woodlands, shrublands, grasslands, and early- and late-seral forests. Range of the western bluebird is displayed in figure 87, volume 2.

Source habitats and special habitat features—Source habitats for family 8 are early-seral and late-seral single-storied montane and lower montane

forests, riparian and upland woodlands, and upland shrub and herblands (table 11). Additionally, burned pine forests likely function as source habitats. Juxtaposition of forested and open areas is a necessary characteristic of source habitats. Snags are a special habitat feature for nesting, although the snags may be relatively small (<53 cm [21 in]) (vol. 3, appendix 1, table 2).

Broad-scale changes in source habitats—Basin-wide, source habitats for the western bluebird declined in 72 percent of watersheds and increased in only 5 percent (fig. 16). These declines are stronger than those observed for most species included in this assessment (table 12). Source habitats have declined in at least 50 percent of watersheds in 9 of the 11 ERUs in which this species occurs (tables 8 and 12). Only the Northern Great Basin and the Owyhee Uplands showed a neutral trend (table 12).

Primary causes for habitat trends and the associated ecological processes—Declines in source habitat resulted from ecologically significant basin-wide declines in early-seral lower montane forest, late-seral lower montane, single-layer forest, upland shrublands, and upland herblands (Hann and others 1997). Of the terrestrial communities providing source habitats for bluebirds, only upland woodlands showed a basin-wide increase from historical to current conditions. There were ecologically significant decreases in upland herblands in all nine ERUs where source habitats declined for bluebirds, and decreases in early- and late-seral single-storied lower montane forests in eight of these nine ERUs. See discussions in families 1, 2, 6, and 10 for additional information on causes for habitat trends and the associated ecological processes.

Our evaluation at the broad-scale did not assess the distribution of foraging habitat in relation to nesting habitat. Additional analysis of the juxtaposition of foraging with nesting habitat is needed at a finer scale of resolution. Results for source habitats shown here for both the current and historical periods are likely overestimates as they do not take into account the need for juxtaposition of habitats.

Other factors that affect the family—Some western bluebirds that breed in the basin migrate to California and Baja California in winter and could be affected by conditions on those wintering grounds.



Figure 16—Trend in source habitats for family 8 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

Issues and strategies for conservation—The primary issues and strategies for family 8 relate to declines in source habitats.

Issues—

1. Reductions in early- and late-seral montane and lower montane forests.
2. Possibly unsustainable conditions in late-seral montane and lower montane forests where large transitions have occurred from shade-intolerant to shade-tolerant species.
3. Reductions and degradation of upland shrublands and herblands.

Strategies—The following strategies could be considered to address issues related to family 8.

1. (To address issue no. 1) Maintain and restore early- and late-seral montane and lower montane forests where these cover types have declined. Both the extent and pattern of these habitats are of concern because source habitats for western bluebirds are found in edge areas.
2. (To address issue no. 2) Restore succession-disturbance regimes to patterns consistent with biophysical variation in those ERUs and portions of ERUs where substantial habitat remains, such as the Northern Great Basin, Owyhee Uplands, or southern portion of Columbia Plateau.
3. (To address issue no. 3) Restore upland shrub and herbland cover types, and manage these areas to maintain plant composition and structure similar to that consistent with the biophysical succession-disturbance regimes. Reduce risk of exotic plant invasion and restore invaded areas to more closely represent native composition and structure.

Family 9—Woodland Family

This family is composed of the two species in group 30, the ash-throated flycatcher and bushtit (table 6). Range maps for these species are shown in figure 90, volume 2.

Source habitats and special habitat features—

Source habitats consist primarily of the upland woodland and upland shrubland community groups, including juniper woodlands, mixed-conifer woodlands, juniper/sagebrush woodlands, Oregon white oak, and mountain mahogany (table 11; vol. 3, appendix 1, table 1). The ash-throated flycatcher also uses old-forest cottonwood-willow. Snags are a special habitat feature for ash-throated flycatchers (vol. 3, appendix 1, table 2).

Broad-scale changes in source habitats—Source habitats for family 9 increased strongly within the basin (fig. 17); specifically, source habitats increased in 70 percent of watersheds and decreased in only 18 percent. Fifty percent or more of the watersheds in 8 of the 10 ERUs containing source habitats had increasing trends: Upper Klamath, Northern Great Basin, Columbia Plateau, Blue Mountains, Northern Great Basin, Owyhee Uplands, Upper Snake, and Snake Headwaters (table 12). Source habitats in the Northern Great Basin represent <1 percent of the ERU. Only the Northern Cascades had a greater number of watersheds with decreasing rather than increasing amount of source habitats. The Southern Cascades generally had a neutral trend.

Primary causes for habitat trends and the associated ecological processes—

Increasing trends in source habitats were due to increases in the juniper/sagebrush cover type. The extent of juniper/sagebrush woodlands has more than doubled in the basin, primarily because of the combined effects of livestock grazing and fire suppression (Hann and others 1997). The upland woodland community group, which includes juniper/sagebrush, underwent ecologically significant increases in five of the eight ERUs that had an increasing habitat trend for family 9. Broad-scale trends in the other source habitat types, especially old-forest cottonwood-willow, Oregon white oak, and mountain mahogany, are difficult to determine at the scale of this analysis (Hann and others 1997).

The increase in woodland extent has produced communities of lower habitat quality than occurred historically. Historical woodland types were typically on soils with scattered clumps of surface rock that protected juniper and other woodland tree species from



Figure 17—Trend in source habitats for family 9 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

fire. The fire regime maintained a somewhat open shrub/herb understory that was high-quality habitat for family 9 species. Historical excessive grazing and fire exclusion has resulted in much higher density of woodland trees and loss of the shrub/herb understory in these native woodland types (Hann and others 1997). Also, as a result of fire exclusion, some of the sagebrush zones have transitioned to dense woodlands of one size class that lacks the structural diversity and snags of native woodlands.

Other factors affecting the family—Insects are the primary prey for these species. Understory shrubs and grasses provide habitat for insects, and excessive grazing can degrade these habitats.

Issues and strategies for conservation—Results of our analysis suggest no cause for broad-scale concern about source habitats for family 9. However, strategies that play a part in overall ecosystem management, and that ensure long-term availability of source habitats for this family, are suggested below.

Issues—

1. Identification and retention of woodlands that are present under inherent succession and disturbance regimes versus identification and reduction of woodlands that exist primarily because of fire exclusion and other land uses.
2. For ash-throated flycatchers, loss of trees with natural cavities or trees suitable for excavation by other species because of juniper removal.
3. Degradation and loss of native understory shrubs and grasses that provide substrates for arthropod prey.

Strategies—The following strategies could be considered to address issues related to species belonging to family 9:

- 1a. (To address issues no. 1 and no. 2) Plan the conversion of juniper to other, more desirable native shrubs and grasses such that blocks of old-growth juniper are retained within and juxtaposed to the

restored areas over space and time. Retention of large or deformed trees and older stands of juniper would benefit species in this family as well as families 6, 7, and 10. Value of older stands of juniper would be highest if stands are retained that have a preponderance of older trees that are hollow or that contain cavities; such trees are used as nest sites by ash-throated flycatchers, especially when located in or near areas dominated by native understory shrubs and grasses. Assure that the retention of woodlands is consistent with the bio-physical succession-disturbance regimes.

- 1b. (To address issues no. 1 and no. 2) Retain representative stands of old-growth western junipers especially in areas containing old junipers with cavities and hollow centers for potential nest sites of ash-throated flycatchers.
2. (To address issue no. 3) Protect and restore native understory shrubs and grasses in source habitats. Reduce risk of exotic plant invasion and restore invaded areas to more closely represent native composition and structure.

Family 10—Range Mosaic Family

Family 10 consists of 17 species of birds, mammals, and reptiles within groups 31 and 32 (table 6). The ranges of the species in this family primarily cover the rangeland ERUs, and several of the species have restricted ranges within only one or two ERUs (vol. 2, figs. 93 and 96).

Source habitats and special habitat features—This family is characterized by species that primarily use various shrublands, herblands, and woodlands. All species in family 10 use several cover types in the upland shrubland and upland herbland community groups as source habitats (table 11). All species except the short-eared owl, pronghorn, Preble's shrew, white-tailed antelope squirrel, and Uinta ground squirrel also use upland woodlands as source habitats. Exotic herbland is an additional source habitat for the ferruginous hawk, burrowing owl, short-eared owl, and lark sparrow. The short-eared owl is the only species in the family that uses riparian herbland.



Figure 18—Trend in source habitats for family 10 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

Several special habitat features have been identified for family 10 (vol. 3, appendix 1, table 2). The burrowing owl requires burrows excavated by other species or natural cavities in lava flows or rocky areas for nest sites; the Preble's shrew uses down logs; the pronghorn antelope is associated with shrub/herb riparian areas for parts of the year; the striped whipsnake and longnose snake use talus areas, and the striped whipsnake also uses cliffs. Many species in this family prefer open cover types with a high percentage of grass and forbs in the understory, either for foraging or nesting.

Broad-scale changes in source habitats—Trends in source habitats were predominantly declining for family 10 (fig. 18). Basin-wide, 52 percent of watersheds exhibited declining trends, whereas 10 percent were projected to have increased. Neutral trends were projected for the remaining area. Watersheds with declining trends were concentrated in the northern half of the basin and in the Snake River drainage, whereas watersheds with neutral trends were mostly in the south-central portions of the basin (fig. 18). Nine ERUs had declining trends in >50 percent of watersheds, and the remaining four had neutral trends in >50 percent of watersheds (table 12). There were no ERUs with predominantly increasing trends.

Individually, all species in family 10 had declining or strongly declining trends in source habitats except for the long-nosed leopard lizard, Mojave black-collared lizard, longnose snake, Wyoming ground squirrel, and white-tailed antelope squirrel, all of which have fairly small and disjunct ranges within the basin (vol. 2, figs 93 and 96). Source habitats for these species were projected to be neutral (table 7).

Primary causes for habitat trends and the associated ecological processes—Upland shrubland and herbland terrestrial communities both had ecologically significant declines (-67 and -31 percent, respectively), whereas upland woodland increased (50 percent) (Hann and others 1997). About 70 percent of the upland shrubland decline transitioned to agriculture on private lands, whereas the decline on public lands was a transition somewhat evenly split among exotic herbland, upland herbland, and upland woodland. About 66 percent of the upland herbland decline transitioned to agriculture on private lands, whereas the decline on public lands was a transition of 13 and 21 percent, respectively, to mid-seral lower montane forest and upland shrubland. Upland woodland was above the

historical maximum across 40 percent of subbasins but below for 34 percent. Dominant transitions for upland woodland increase came from upland shrubland, whereas decreases went to upland herbland. Declines in woodland came primarily from the loss of aspen and cottonwood woodland types through excessive livestock grazing and lack of fire in the northeastern and eastern portions of the basin, whereas increases came from increased juniper woodland types in the south-central and western portions of the basin.

In general, patch habitat quality for family 10, the herbland, shrubland, and woodland source habitats, declined from historical to current periods because of conversion to agriculture, successional transitions caused by fire exclusion, and excessive livestock grazing. Current upland shrubland and upland herbland patches were found to have higher canopy closure of shrubs, less species and layer diversity of understory shrubs and herbs, and less herbaceous productivity (Hann and others 1997). Almost two thirds of upland shrubland patches were estimated to contain some component of exotic plant species, and at least one third was estimated to have an understory dominated by exotic plant species. Current upland herbland patches were found to have lower canopy closure of grasses and less diversity of species and layers, with lower productivity of herbs, as compared to historical conditions. The communities with transitions to and from upland woodland may be the ecosystems most at risk. Dense upland woodlands created through transition from upland shrubland because of fire exclusion and excessive livestock grazing were found to often have nutrient-limited soils that limit the ability of understory herbaceous species to regenerate and provide soil cover. This lack of understory plant cover may be exacerbating erosion of surface soils in steep terrain, thereby reducing site capability. Limited nutrients also may be tied up in the juniper foliage and lost when intense summer wildfires occur.

Trends of watershed change for family 10 source habitats were highly spatially disjunct (fig. 18). Decreases occurred extensively across the western, northern, central, and eastern portions of the basin. Neutral trends occurred in a concentrated area of the south-central portion of the basin, and increases were minor. These changes occurred in response to extensive fire exclusion, agricultural development, exotic invasions, and excessive livestock grazing across the more productive portions of the basin. The watersheds

exhibiting neutral or positive trends would, if investigated at a finer scale, likely show a decrease in source habitat because of extensive decline in fine-scale habitat quality. Because of the invasion of exotics, the historical effects of excessive livestock grazing, the permanent loss of many habitats to agricultural conversion, and a 95-percent change in frequency and severity of fire, we conclude there is little that is similar to historical conditions for this terrestrial family.

Other factors affecting the family—Losses of native perennial grass and forb understories within the upland shrublands, because of excessive livestock grazing combined with cheatgrass and other exotic plant invasions, are microhabitat features that cannot be evaluated directly with the broad-scale analysis. Because species in family 10 favor grass or shrub-grass types for nesting, foraging, or hiding, we know that the grass component of historical shrublands was important. Wiens and Rotenberry (1981) found significant correlations between the coverage of grass and the densities of both western meadowlarks ($r = 0.62$, $P < 0.001$) and lark sparrows ($r = 0.37$, $P < 0.05$). Forbs comprise most of pronghorn diets during spring and summer, and livestock grazing decreases the abundance of forbs (Yoakum 1980). Removal of grass cover by livestock potentially has detrimental effects on the short-eared owl (Marti and Marks 1989). Areas dominated by dense stands of cheatgrass or other exotic plants may preclude use by longnose leopard lizards (Stebbins 1985), longnose snakes (Beck and Peterson 1995), and collared lizards.

Microbiotic, or cryptogamic crust, is projected to have been widely distributed throughout the source habitats for this group, particularly in the Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs but also scattered in the Columbia Plateau ERU (Hann and others 1997, map 3.59). Evidence indicates that microbiotic crusts improve soil stability, productivity, and moisture retention; moderate extreme temperatures at the soil surface; and enhance seedling establishment of vascular plants (Belnap and Gardner 1993, Harper and Pendleton 1993, Johansen and others 1993, St. Clair and others 1993). The BLM in Idaho has recognized the potential importance of microbiotic crusts by proposing standards for rangeland health that include the maintenance of these crusts to ensure proper functioning and productivity of native plant communities (USDI Bureau of Land Management 1997). These crusts were widely destroyed by trampling during the excessive livestock grazing of the late

1800s and early 1900s (Daubenmire 1970, MacCracken and others 1983, Mack and Thompson 1982, Poulton 1955). Currently, high-intensity grazing and altered fire regimes modify shrub-steppe plant communities and threaten the maintenance and recovery of microbiotic crusts (Belnap 1995, Kaltenecker 1997, St. Clair and Johansen 1993).

Soil compaction caused by livestock grazing could negatively affect both the longnose snake and ground snake. These burrowers benefit from loose, sandy, and friable soils (Beck and Peterson 1995, Nussbaum and others 1983).

Human activities associated with roads are known to impact ferruginous hawks, short-eared owls, burrowing owls (Bechard and Schmutz 1995, Green and Anthony 1989, Lokemoen and Duebber 1976, Olendorff and Stoddart 1974, Ramakka and Woyewodzic 1993, Schmutz 1984, White and Thurow 1985) and western meadowlarks (Lanyon 1994). Harassment of pronghorn by snowmachines and all-terrain vehicles stresses animals at all times of the year (Autenrieth 1978). Accidental and deliberate mortality of snakes potentially increase in direct proportion to roading and traffic in the basin. Although the three species of snakes in this family may not be as frequently killed by vehicles as are some more common species (such as gopher snake and western rattlesnake), increasing human access to source habitats likely will result in more deliberate killing of snakes. Because reptiles are increasingly popular as pets, all reptile species in this group, particularly the lizards, likely are impacted by collecting (Lehmkuhl and others 1997). Road access intensifies the pressure on reptile populations by increasing the ease with which reptiles can be collected.

Poisoning and other eradication potentially affect populations of all four species of ground squirrels. Ground squirrels also are popular targets for recreational shooting. The typically small size of Washington ground squirrel colony populations makes them particularly vulnerable to extirpation (Tomich 1982). Recreational shooting of marmots and ground squirrels impacts burrowing owls because the owls are accidentally or deliberately shot (Marti and Marks 1989). Pesticide use leads to direct mortality in burrowing owls, short-eared owls (Marti and Marks 1989), and western meadowlarks (Griffin 1959). Pesticides may also reduce populations of burrowing owls through a reduction in the populations of burrowing mammals.

Pronghorn movement is restricted or completely impeded by net-wire and other fences that prevent them from crossing beneath the lower strand (Helms 1978, Oakley and Riddle 1974, Yoakum 1980). Roads are readily crossed by pronghorn, but snow accumulating in roadside ditches also may present barriers to movement during winter (Bruns 1977).

Issues and strategies for conservation—The primary issues for family 10 relate to source habitats, special habitat features, and road-related human disturbances.

Issues—

1. Permanent and continued loss of large acreage of upland shrublands and upland herblands because of conversion to agriculture, brush control, cheatgrass invasion, and excessive livestock grazing.
2. Loss of native perennial grass and forb understories within the upland shrublands.
3. Soil compaction and loss of the microbiotic crust.
4. Adverse effects of human disturbance and roads as a facilitator of these effects.

Strategies—The following strategies could be considered to address issues related to species belonging to family 10:

- 1a. (To address issue no. 1) Identify and conserve large areas of remaining native upland shrublands and upland herblands where ecological integrity is still relatively high, and manage to promote their long-term sustainability. Large contiguous blocks of public land in the Northern Great Basin and Owyhee Uplands could be considered, as well as native vegetation that currently exists on military lands in Washington (Rickard and Poole 1989, Schuler and others 1993, Smith 1994).
- 1b. (To address issue no. 1) Conduct mid-scale step-down assessment of current conditions relative to landscape patterns of succession-disturbance regimes. Focus short-term restoration of watersheds on those that are in high departure, do not contain susceptible populations of species of high conservation concern and that are at high risk of loss of biophysical capability.

2. (To address issue no. 2) Restore the native grass and forb components of the upland woodland, shrubland, and grassland community groups to historical levels throughout the basin. Restoration measures include seedings and plantings in combination with effective methods of site preparation, effective management of grazing by domestic and wild ungulates, and control of human activities such as offroad vehicle usage and other ground-disturbing factors.
3. (To address issue no. 3) Reduce causes of soil compaction, particularly within source habitats of the longnose snake and ground snake. This factor may be important in the Owyhee Uplands ERU in particular. Restore the microbiotic crust in ERUs with potential for redevelopment, specifically the Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs and, to a lesser extent, the Columbia Plateau ERU.
4. (To address issue no. 4) Reduce the negative effects of factors associated with roads. These include the indiscriminate poisoning and recreational shooting of ground squirrels, accidental and deliberate killing of snakes and lizards, the capture of reptiles as pets, and the poaching and disturbance of pronghorn populations.
5. (To address issue no. 4) To the extent possible, encourage activities that reduce mortality and stress on species in family 10. For example, modify existing fences and construct new fences in pronghorn range to allow passage by pronghorns (Yoakum 1980); modify agricultural practices to minimize direct mortality of nesting birds (Clark 1975); and reduce use of pesticides when feasible.

Family 11—Sagebrush Family

This family consists of groups 33, 34, and 35. The included species are listed in table 6; example species are sage grouse, loggerhead shrike, pygmy rabbit, and kit fox. The species ranges within this family are generally located throughout the primarily rangeland type communities across the basin (vol. 2, figs. 99, 102, and 105).

Source habitats and special habitat features—Species in family 11 group together based on their nearly common use of open and closed low-medium



Figure 19—Trend in source habitats for family 11 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

shrub stages of big sagebrush, low sage, and mountain big sagebrush (table 11; vol. 3, appendix 1, table 1). Other important source habitats include salt desert shrub, antelope bitterbrush-bluebunch wheatgrass, and herbaceous wetlands. Four species (sage thrasher, brewer's sparrow, sage sparrow, and loggerhead shrike) also use upland woodlands. Special habitat features include riparian meadows (sage grouse), and burrows (kit fox).

Broad-scale changes in source habitats—Source habitats are limited in the Northern Cascades, Southern Cascades, Northern Glaciated Mountains, and Lower Clark Fork ERUs, with few watersheds containing habitats for few species within this family (vol. 2, figs. 100, 103, and 106). Overall, 42 percent of the watersheds in the basin had declining trends, and 45 percent had neutral trends (fig. 19). Of the eight ERUs that contained a substantial number of watersheds with source habitats, five showed overall neutral trends (Upper Klamath, Northern Great Basin, Columbia Plateau, Blue Mountains, Owyhee Uplands, and Central Idaho Mountains), and three showed declining trends (Upper Clark Fork, Upper Snake, and Snake Headwaters) (table 12). Fifty percent of the watersheds in the Columbia Plateau showed a declining trend.

Habitat loss on an absolute scale ranged from -9 percent for the loggerhead shrike (group 35) to -15 percent for group 33, which contains the sage grouse, sage thrasher, and pygmy rabbit among others (table 9). All of the species in this group except the kit fox showed relative declines ≥ 20 percent across the basin (table 7). Wet meadows and riparian vegetation, cover types used for brood-rearing by sage grouse, have declined substantially since historical times (Lee and others 1997, Quigley and others 1996).

No information is available to determine whether changes in availability of burrows for kit fox dens, or in soil conditions needed for burrow excavation, have occurred in the basin. A lack of suitable loose-textured soil for burrow construction may be a natural limiting factor for kit fox in southeastern Oregon (Keister and Immell 1994). Two other species in this family, pygmy rabbit and sagebrush vole, construct their own burrows, and any factors that may negatively affect soil texture or quality may negatively affect these species as well. Voles seldom use compacted or rocky

soil (Maser and others 1974) and may be absent from areas that have suffered soil erosion because of heavy livestock grazing (Maser and Strickland 1978).

Primary causes for habitat trends and the associated ecological processes—Trends of these habitats can be taken in similar context as family 10. That is, the same patterns of broad-scale redistribution of habitats, broad-scale reduction, and fragmentation and simplification of habitats at multiple spatial scales (as described by Hann and others 1997) were associated with family 11 habitats in a similar manner as those associated with family 10.

The major cause for change in source habitats for groups in family 11 has been a significant loss of upland shrubland habitat, which showed the largest decline (-11 percent) of any terrestrial community basin-wide (Hann and others 1997). The single largest loss in cover types within the basin was the decline in big sagebrush (-8 percent), which is considered source habitat for all species within this family. The large-scale loss of upland shrubland habitat was attributed to several factors, including the increase in agriculture and the conversion of lands to other exotic forbs and annual grasses. The largest transition of any terrestrial community was from upland shrubland to agriculture (+9 percent) (Hann and others 1997). The ERUs with the biggest changes were the Columbia Plateau and Upper Snake. The former is now nearly half agricultural lands, whereas the latter is nearly one-third. Agriculture also now occupies over a tenth of the Owyhee Uplands.

The abundance of upland woodlands, primarily the juniper/sagebrush cover type, increased significantly (from less than 1 percent to about 2 percent) basin-wide (Hann and others 1997), which in some cases may have offset the relative losses shown in the upland shrublands.

Much of the area that at the broad scale is mapped as source habitat currently may, in fact, at a finer scale be unsuitable because of changes in soil or understory vegetation. Altered fire regimes and livestock grazing in many areas have removed much of the native herbaceous understories, which are important habitat features for several members of this group. In some areas, native herbaceous understories also have been replaced by unsuitable exotic vegetation.

Habitat condition for family 11 can be described by the composite ecological integrity ratings (Quigley and others 1996) that show most of the habitat to have a “low” rating. Many of the subbasins that have a “low” rating include lands used for agricultural and grazing uses. Primary risks to the ecological integrity over most of the area with source habitats for this family include overgrazing, exotic grass and forb invasion, and continued declines in herbland and shrubland habitats (Quigley and others 1996).

Other factors affecting this family—Grazing and altered fire regimes have been linked to continued losses of microbiotic crusts (Belnap 1995, Kaltenecker 1997, St. Clair and Johansen 1993). There is increasing evidence that microbiotic crusts improve soil productivity and moisture retention, moderate extreme temperatures at soil surfaces, and enhance seeding establishment of vascular plants (Belnap and Gardner 1993, Harper and Pendleton 1993, Johansen and others 1993, St. Clair and others 1993). The effects of past losses and continued threats to microbiotic crusts across the basin may affect restoration efforts of upland herbland and shrubland environments.

Little information is available on effects of landscape patterns on species in this family. Research by Knick and Rotenberry (1995) indicates that both the sage thrasher and sage sparrow are more likely to be found in areas with larger patches of habitat as compared to the Brewer’s sparrow, which is known to occupy small patches of suitable habitat within a matrix of unsuitable vegetation.

Several species in this family are known to be negatively affected by human disturbance from various causes. Kit fox are vulnerable to poisoned baits placed to destroy coyotes (Orloff and others 1986). Vehicular collisions may be an important source of mortality of loggerhead shrikes because shrikes often forage and nest along roads (Blumton 1989, Craig 1978, Flickinger 1995, Yosef 1996). Lastly, roads and associated human disturbance can be especially harmful to grouse during the lekking and wintering periods (Marks and Saab 1987, Saab and Marks 1992).

The sage sparrow, Brewer’s sparrow, and lark bunting are infrequently parasitized by brown-headed cowbirds (Ehrlich and others 1988). The sage thrasher also is parasitized but rejects cowbird eggs (Rich and Rothstein 1985).

Issues and strategies for conservation—

1. Loss of and degradation of sagebrush habitats because of conversion to agriculture, altered fire regimes, and livestock grazing. A change in fire regimes and livestock grazing has left much of the area susceptible to invasion of cheatgrass and other nonnative vegetation. Altered fire regimes and livestock grazing also may have played a role in the loss of microbiotic crusts.
2. Adverse effects of human disturbance.
3. Redistribution, fragmentation, and simplification of habitats outside of the HRV (per Hann and others [1997]).

Strategies—The following strategies could be considered to address issues related to species belonging to family 11. Primary strategies for improvement of source habitats for family 11, outlined below, are similar to many strategies identified for family 10:

1. (In support of issue no. 1) Identify and conserve remaining core areas of shrub-steppe and other source habitats where ecological integrity is still high (Quigley and others 1996); examples are the Northern Great Basin and Owyhee Uplands ERUs that contain large blocks of public land. Conservation measures include control of cheatgrass and other exotic plants, proper management of grazing by domestic and wild ungulates, and maintenance of the Conservation Reserve Program on private lands. Conservation of large core areas will provide long-term habitat stability; such areas will function as anchor points for restoration, corridor connections, and for other key functions of landscape management.
2. (In support of issue no. 1) Restore the native grass, forb, and shrub composition within the sagebrush cover types, and in other shrubsteppe cover types used by species in family 10. Restore selected areas of cheatgrass monocultures, by using seedings and other manipulations, for areas that would provide key spatial links for populations in family 10.
3. (In support of issue no. 1) Retard the spread of nonnative vegetation. Use fire prevention and suppression, planting of fire-resistant vegetation, and explore the use of “green-stripping” techniques to



Figure 20—Trend in source habitats for family 12 within each of 2,562 watersheds in the interior Columbia basin. Trend for each watershed is shown as one of three categories: increasing, decreasing, or no change. A watershed was classified as increasing if >50 percent of the groups in a family increased in source habitats >20 percent, considering only those groups that occurred in the watershed. A watershed was classified as decreasing if >50 percent of the groups in a family decreased in source habitats >20 percent, considering only those groups that occurred in the watershed. Watersheds not classified as increasing or decreasing were classified as no change.

control the spread of cheatgrass in areas that are susceptible to cheatgrass invasion and that are currently dominated by native shrubsteppe vegetation.

4. (In support of issue no. 1) Restore the microbiotic crust in ERUs with potential for redevelopment (that is areas near propagule sources, and with suitable soil, vegetation, and climatic characteristics [see Belnap 1993, Belnap 1995, Kaltenecker 1997, Kaltenecker and Wicklow-Howard 1994]); specifically focus on the Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs and, to a lesser extent, the Columbia Plateau ERU (Hann and others 1997, map 3.59).
5. (In support of issue no. 1) Maintain or restore riparian vegetation and associated water tables to benefit microhabitats for sage grouse through rangeland management (for example, grazing management of domestic and wild ungulates).
6. (In support of issue no. 2) Minimize adverse effects of human disturbance. Implement road closures or other management that reduces human activities and presence in source habitats.
7. (In support of issue no. 3) Conduct midscale step-down assessment of current conditions relative to landscape patterns of succession-disturbance regimes. Focus short-term restoration of watersheds on those that are in high departure, do not contain susceptible populations of species of high conservation concern, and are at high risk of loss of biophysical capability.

Family 12—Grassland and Open-Canopy Sagebrush Family

Family 12 consists of the four species in groups 36 and 37: Columbian sharp-tailed grouse (summer), clay-colored sparrow, grasshopper sparrow, and Idaho ground squirrel (table 6). The sharp-tailed grouse and Idaho ground squirrel are year-round residents, whereas the grasshopper sparrow and clay-colored sparrows breed only in the basin. Most species in this family have limited or reduced distributions, or both (vol. 2, figs. 108 and 111).

Source habitats and special habitat features—Membership in family 12 was based on their close associations with upland herblands, primarily fescue-

bunchgrass but, additionally, all species except the clay-colored sparrow use open-canopied sagebrush communities (table 11; vol. 3, appendix 1, table 1). Additional cover types used by one or more species are chokecherry-serviceberry-rose, wheatgrass bunchgrass, native forbs, and herbaceous wetlands.

Although no special habitat features were identified for species in family 12, microhabitat characteristics probably limit these species' distributions within the source habitats identified above. Sharp-tailed grouse use areas in more mesic (>30 cm [12 in] of annual precipitation) shrublands and grasslands (Meints and others 1992) and where the topography is rolling (Saab and Marks 1992). Winter habitat for sharp-tailed grouse, primarily mountain and riparian shrubs, was not modeled here because of the fine-scale nature of those specific cover types. The clay-colored sparrow may be attracted to sites that have dense shrubs in a matrix of more open grasslandlike vegetation (Janes 1983). Lastly, the Idaho ground squirrel inhabits meadows dominated by shallow soils and small intrusions of deeper soil for nest burrows (USDA Forest Service and USDI Fish and Wildlife Service 1996); such meadows are typically surrounded by ponderosa pine forests.

Broad-scale changes in source habitats—Restricted ranges and reductions in ranges of most species in family 12 increase the susceptibility of these populations to habitat declines, which occurred consistently and strongly across most or all ERUs (table 12) and associated watersheds (fig. 20). Source habitats declined in 60 percent of the watersheds throughout the basin. Specifically, source habitats declined in eight ERUs (Northern Cascades, Southern Cascades, Upper Klamath, Columbia Plateau, Blue Mountains, Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork) (table 12). Greater than 45 percent of the watersheds in the Owyhee Uplands, Snake Headwaters, and Central Idaho Mountains also had declining trends, whereas >65 percent of the watersheds in the Northern Great Basin and Upper Snake had neutral trends.

Primary causes for habitat trends and the associated ecological processes—Trends of source habitats for family 12 can be taken in similar context as for families 10 and 11. That is, the same patterns of broad-scale redistribution of habitats, and of broad-scale

reduction, fragmentation, and simplification of habitats at multiple spatial scales (as described by Hann and others 1997) were associated with family 12.

Declines in source habitats for family 12 resulted from basin-wide declines that occurred primarily in upland shrubland and upland herblands (Hann and others 1997). The largest declines of terrestrial communities basin-wide were upland shrublands (-11 percent) and upland herblands (-10 percent) (Hann and others 1997). The two largest decreases in cover types across the basin were big sagebrush (-8 percent) and fescue-bunchgrass (-5 percent).

The open-canopy low-medium structural stage of mountain big sagebrush and big sagebrush experienced some of the greatest absolute declines on an ERU basis. The combined absolute decline for the open-canopy low-medium structural stage of these two sagebrush types declined in the Upper Snake (-40 percent), Owyhee Uplands (-20 percent), Columbia Plateau (-13 percent), Snake Headwaters (-7 percent), and Northern Great Basin (-2 percent) (vol. 3, appendix 1, table 4). In these open-canopied cover types, shrubs and trees eventually invade much of the area that was occupied by grasses and forbs when fire is absent. Woody species tie up nitrogen and other trace nutrients causing a decline in site productivity. Subsequently, foliage cover, basal cover, and litter from the grasses and forbs decline, causing exposure of the surface soil, which leads to erosion. Erosion potentials in these areas can be aggravated by excessive livestock grazing (as well as excessive grazing by wild ungulates in concentrated areas, typically only on winter range). Once the surface soil becomes eroded and the subsoil is exposed, the environment becomes more conducive to other woody species that better compete for subsoil moisture.

Bunchgrasses, critical habitat components for family 12, were substantially impacted by high-intensity grazing in the late 1800s and early 1900s (USDA Forest Service 1996). For the Idaho ground squirrel, meadow habitats of sagebrush and herbaceous vegetation surrounded by pine forest are decreasing because of forest encroachment (USDA Forest Service and USDI Fish and Wildlife Service 1996).

Fire can either enhance or degrade habitats for species in this family depending on cover type, timing, frequency, intensity, size of burn, soils, and precipitation.

It is likely that all species in family 12 avoid burns immediately after the fire because of loss of grass or shrub cover, and return to burned sites after grasses are restored. Most species of sagebrush do not resprout and may not regenerate for 5 to 15 years after fires. In contrast, many species of deciduous shrubs (for example chokecherry-serviceberry-rose) usually resprout immediately after fire. Also, exotic vegetation can invade after fire, depending on the soils and precipitation.

Mountain shrubs (chokecherry-serviceberry-rose), shrub-wetlands, and herbaceous wetlands, other source habitats that are key components of sharp-tailed grouse habitat during late summer, fall, and winter, naturally occur in small patches and were difficult to map at the scale of this analysis. Accurate information, therefore, was not available on habitat trends in mountain shrub and wetland cover types

Other factors affecting the family—Grazing can negatively affect grasshopper sparrows (Bock and Webb 1984, Saab and others 1995), and sharp-tailed grouse (Marks and Saab Marks 1987, Saab and Marks 1992). High-intensity grazing negatively affects the other species of this group (clay-colored sparrows and Idaho ground squirrels) because of losses of native perennial grasses and forbs, which are essential habitat components for these species.

Grazing and altered fire regimes have been linked to continued losses of microbiotic crusts (Belnap 1995, Kaltenecker 1997, St. Clair and Johansen 1993). Increasing evidence shows that microbiotic crusts improve soil productivity and moisture retention, moderate extreme temperatures at soil surfaces, and enhance seeding establishment of vascular plants (Belnap and Gardner 1993, Harper and Pendleton 1993, Johansen and others 1993, St. Clair and others 1993). The effects of past losses and continued threats to microbiotic crusts across the basin may affect restoration efforts of upland herbland and shrubland environments.

Where hayfields and similar agricultural lands have replaced native source habitats or are now located adjacent to such habitats, substantial mortality can be associated with annual tillage, particularly for grasshopper sparrow. Early season mowing of hayfields causes major nest failures in grassland-nesting species (Knapton 1994, Smith 1963).

Human disturbances related to the expansion of residential developments, increases in road densities, and associated recreational activities may exacerbate losses of suitable habitat within the historical range of Columbian sharp-tailed grouse (Giesen and Connelly 1993, Tirhi 1995). Idaho ground squirrel populations are susceptible to sport shooting (Moroz and others 1995) as well as loss of habitat from human developments (USDA Forest Service and USDI Fish and Wildlife Service 1996). The clay-colored sparrow and grasshopper sparrow also are susceptible to continued loss in habitat because of continued expansion of residential developments.

Issues and strategies for conservation—The magnitude and consistency of declines in source habitats for family 12 were as strong as or stronger than those experienced for any other family, with the possible exception of family 1. Such declines are reinforced by the strength and consistency of habitat declines that we observed at a species level for members of this family (tables 7 and 8). Declines in source habitats for the Idaho ground squirrel, grasshopper sparrow, and clay-colored sparrow were second, third, and fifth highest among all species in the basin (table 7). Moreover, declines in source habitats for the Columbian sharp-tailed grouse were in the upper 20 percent of all species-level declines (table 7).

Issues—

1. Loss of upland herbland and upland shrubland vegetation basin-wide.
2. Degradation of upland herbland and upland shrublands habitats because of invasions of exotic forbs and grasses, excessive livestock grazing, altered fire regimes, and herbicide and pesticide use.
3. Human disturbance and human encroachment, and roads as a facilitator of these negative effects.
4. Isolated and disjunct populations for Columbian sharp-tailed grouse and Idaho ground squirrels.
5. Redistribution, fragmentation, and simplification at basin, ERU, subbasin, watershed, and patch scales compared to HRV (per findings of Hann and others [1997]).

Strategies—The following strategies could be considered to address issues related to species belonging to family 12. The large and widespread declines in source habitats for species in family 12 are notable and compelling from a management perspective. Strategies to improve source habitats for this family partially overlap with strategies for families 10 and 11:

1. (In support of issue no. 1) Identify and conserve remaining large areas of open-canopied big sagebrush, fescue-bunchgrass, mountain big sagebrush, wheatgrass bunchgrass, native forbs and other source habitats where source habitats have not declined strongly, such as in the Northern Great Basin, Upper Snake, and Snake Headwaters ERUs. Conservation measures include control of cheatgrass and other exotic plants; reductions in grazing by domestic and wild ungulates; and maintenance of or increased participation in the Conservation Reserve Program on private lands. Conservation of large areas will provide long-term habitat stability; such areas will function as anchor points for restoration, corridor connections, and for other key functions of landscape management.
2. (In support of issue no. 2) Restore the historical composition of native grasses, forbs, and shrubs within the big, mountain big, and low sagebrush, fescue- and wheatgrass bunchgrass, native forb, and chokecherry-serviceberry-rose cover types used by species in family 12, in all ERUs that have undergone strong declines in source habitats. Restoration measures include seedings and plantings in combination with effective methods of site preparation, reductions in grazing pressure by domestic and wild ungulates, control of invading exotic plants, reductions in human activities such as offroad vehicle usage, control of road access and associated motorized traffic, and control of other ground-disturbing factors not part of site preparation.
3. (In support of issue no. 2) Restore the microbiotic crust in ERUs with potential for redevelopment (i.e., areas near propagule sources, and with suitable soil, vegetation, and climatic characteristics [see Belnap 1993, Belnap 1995, Kaltenecker 1997, Kaltenecker and Wicklow-Howard 1994]): Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs and, to a lesser extent, the Columbia Plateau ERU (Hann and others 1997, map 3.59).

4. (In support of issue no. 3) Reduce the negative effects of factors associated with roads on species in family 12 (tables 13 and 14). Negative effects associated with roads include human disturbance of sharp-tailed grouse leks and recreational shooting of Idaho ground squirrels. Example mitigations include seasonal road closures during the grouse lekking period and restrictions on recreational shooting of ground squirrels.
5. (In support of issue no. 4) Restore historical, native composition of meadow vegetation within the range of the Idaho ground squirrel; augment restoration with possible measures to control populations of Columbian ground squirrels, which may have a competitive advantage with the Idaho ground squirrel in areas of sympatry.
6. (In support of issue no. 4) Hasten recovery of populations of sharp-tailed grouse through the use of translocations in areas where habitats have undergone restoration or are deemed to be of sufficient quality and size to support the species' long-term persistence. Use land transactions to consolidate areas containing suitable habitats, or that could be restored to suitability, as part of translocation strategies.
7. (In support of issue no. 5) Conduct midscale step-down assessment of current conditions relative to landscape patterns of succession-disturbance regimes. Focus short-term restoration of watersheds on those that are in high departure, do not contain susceptible populations of species of high conservation concern, and are at high risk of loss of biophysical capability.

Species Negatively Affected by Factors Associated With Roads

Species-Road Relations

Various road-associated factors can negatively affect habitats and populations of terrestrial vertebrates (Bennett 1991, Forman and Hersperger 1996, Forman and others 1997, Mader 1984, Trombulak and Frissell 2000). We identified 13 factors that were consistently associated with roads in a manner deleterious to terrestrial vertebrates (table 13), based on results from

a plethora of studies conducted in Europe, North America, and Australia (with examples of this literature cited in table 13). Effects of road-associated factors can be direct, such as habitat loss and fragmentation (Miller and others 1996, Reed and others 1996) or indirect, such as population displacement or avoidance in areas near roads in relation to motorized traffic and associated human activities (Mader 1984). Indirect effects can be subtle, such as the negative effects of all-terrain vehicles (Busack and Bury 1974, Lukenbach 1978) that can and do travel over a myriad of off-road and on-road conditions, and whose movements are facilitated by road access.

Based on the factors listed in table 13, >70 percent of the 91 broad-scale species of focus were found to be negatively affected by one or more factors associated with roads (table 14). Negative factors associated with roads, and their specific effects on habitats and populations, are diverse and not always easily recognized. These factors go beyond the obvious, direct effects of habitat loss from road construction and maintenance, which affects all species. Despite the diversity of factors and effects, several generalizations are obvious from the summaries in table 13 and from the literature cited in table 14:

1. Road construction converts large areas of habitat to nonhabitat (Forman 2000, Hann and others 1997, Reed and others 1996); the resulting motorized traffic facilitates the spread of exotic plants and animals, further reducing quality of habitat for native flora and fauna (Bennett 1991, Hann and others 1997). Roads also create habitat edge (Mader 1984, Reed and others 1996); increased edge changes habitat in favor of species that use edges, and to the detriment of species that avoid edges or experience increased mortality near or along edges (Marcot and others 1994).
2. Species that depend on large trees, snags, or down logs, particularly cavity-using birds and mammals, are vulnerable to increased harvest of these structures along roads (Hann and others 1997). Motorized access facilitates firewood cutting, as well as commercial harvest, of these structures.
3. Several large mammals are vulnerable to poaching, such as caribou, pronghorn, mountain goat, bighorn sheep, wolf, and grizzly bear (e.g., Dood and others 1985, 1986; Knight and others 1988; McLellan and

Table 13—Road-associated factors that negatively affect habitats or populations of terrestrial vertebrates, a generalized description of each factor’s effect in relation to roads, and example citations linking roads as a facilitator of the factors and effects

Road-associated factor	Effect of factor in relation to roads	Example citations
Snag reduction	Reduction in density of snags due to their removal near roads, as facilitated by road access	Hann and others (1997), Quigley and others (1996)
Down log reduction	Reduction in density of large logs due to their removal near roads, as facilitated by road access	Hann and others (1997), Quigley and others (1996)
Habitat loss and fragmentation	Loss and resulting fragmentation of habitat due to establishment and maintenance of road and road right-of-way	Forman and others (1997), Reed and others (1996)
Negative edge effects	Specific case of fragmentation for species that respond negatively to openings or linear edges created by roads (such as habitat-interior species [Marcot and others 1994])	Forman and others (1997), Mader (1984), Reed and others (1996)
Over-hunting	Nonsustainable or nondesired legal harvest by hunting, as facilitated by road access	Christensen and others (1991), Unsworth and others (1993)
Over-trapping	Nonsustainable or nondesired legal harvest by trapping, as facilitated by road access	Bailey and others (1986), Hodgman and others (1994)
Poaching	Increased illegal take (shooting or trapping) of animals, as facilitated by road access	Cole and others (1997), McLellan and Shackleton (1988)
Collection	Collection of live animals for human uses (e.g., amphibians and reptiles collected for use as pets), as facilitated by the physical characteristics of roads or by road access	Nussbaum and others (1983)
Harassment or disturbance at specific use sites	Direct interference of life functions at specific use sites due to human or motorized activities, as facilitated by road access (e.g., increased disturbance of nest sites, breeding leks, or communal roost sites)	Forman (1995), White (1974)
Collisions	Death or injury resulting from a motorized vehicle running over or hitting an animal on a road	Blumton (1989), Boarman and Sazaki (1996), Vestjens (1973)
Movement barrier	Preclusion of dispersal, migration, or other movements as posed by a road itself or by human activities on or near a road or road network	Bennett (1991), Mader (1984)
Displacement or avoidance	Spatial shifts in populations or individual animals away from a road or road network in relation to human activities on or near a road or road network	Forman and Hersperger (1996), Mech and others (1988)
Chronic, negative interactions with humans	Increased mortality of animals (e.g., euthanasia or shooting of gray wolves or grizzly bears) due to increased contact with humans, as facilitated by road access	Mace and others (1996), Thiel (1985)

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

Group	Species	Snag reduction	Down log reduction	Negative edge effects	Over-hunting	Over-trapping	Poaching	Collection	Harassment	Collisions	Movement barrier	Displacement	Chronic, negative interactions
6	Golden-crowned kinglet			B									
6	Hammond's flycatcher			B									
6	Hoary bat	A											
6	Pileated woodpecker	A	A	B									
6	Silver-haired bat	A											
6	Vaux's swift	A		B									
6	Varied thrush												
6	Williamson's sapsucker	A		B									
6	Winter wren	A	A	B									
7	Boreal owl	A		B									
8	Great gray owl	A											
9	Black-backed woodpecker	A		B									
10	Olive-sided flycatcher												
11	Three-toed woodpecker	A		B									

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

Group	Species	Snag reduction	Down log reduction	Negative edge effects	Over-hunting	Over-trapping	Poaching	Collection	Harassment	Collisions	Movement barrier	Displacement	Chronic, negative interactions
11	White-winged crossbill									69*			
12	Woodland caribou			B			13*			13*			
13	N. flying squirrel	A	A	B									
14	Hermit warbler			B									
15	Pygmy shrew										C		
15	Wolverine		A			47, 55			68				
16	Lynx		A			31*, 32			33				
17	Blue grouse (summer)								34				
17	Mountain quail (summer)								34				
18	Lazuli bunting												
19	Gray wolf			18*			16*, 17, 20, 21, 22, 72			17*, 20*, 21, 22*, 72		15*, 18*, 19*, 23*, 72	16, 19*, 17, 20, 22, 70*, 72
19	Grizzly bear						24, 25, 26, 14*, 72			24*, 26*, 72		14*, 25*, 28*, 29*, 30*, 72	24, 14*, 30*, 72
20	Mountain goat				40		C		39, 41	38*		39*	
21	Long-eared owl												
22	California bighorn sheep				C		C		66			C	

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

Group	Species	Snag reduction	Down log reduction	Negative edge effects	Over-hunting	Over-trapping	Poaching	Collection	Harassment	Collisions	Movement barrier	Displacement	Chronic, negative interactions
22	Rocky Mt. bighorn sheep				65		65		44			42, 43, 57	
23	Broad-tailed hummingbird												
23	Rufous hummingbird												
24	Black-chinned hummingbird												
24	California mountain kingsnake							35, 67		36*			
24	Sharptail snake		A					67		36*			
25	N. goshawk (winter)												
26	Fringed myotis	A					7, 71		7, 71				
26	Long-eared myotis	A					7, 71		7, 71				
26	Long-legged myotis	A					7, 71		7, 71				
26	Yuma myotis						7, 71		7, 71				
27	Townsend's big-eared bat						7, 8, 71		7, 8, 71			7, 8	

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

[illegible]

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

Group	Species	Snag reduction	Down log reduction	Negative edge effects	Over-hunting	Over-trapping	Poaching	Collection	Harassment	Collisions	Movement barrier	Displacement	Chronic, negative interactions
32	Ground snake							56, 67		C			
32	Longnose leopard lizard							56, 67		C			
32	Longnose snake							56, 67		C			
32	Mojave black-collared lizard							56, 67		C			
32	Preble's shrew		A								C		
32	Striped whipsnake							56, 67		C			
32	Uinta ground squirrel				C		C						
32	Washington ground squirrel				C		C						
32	White-tailed antelope squirrel				C		C						
32	Wyoming ground squirrel				C		C						
33	Brewer's sparrow												
33	Lark bunting												
33	Pygmy rabbit												
33	Sagebrush vole										C		
33	Sage sparrow												

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

[illegible]

Table 14—Effects of road-associated factors on habitats and populations of broad-scale species of focus^a (continued)

Group	Species	Snag reduction	Down log reduction	Negative edge effects	Over-hunting	Over-trapping	Poaching	Collection	Harassment	Collisions	Movement barrier	Displacement	Chronic, negative interactions
39	Lewis' woodpecker (resident)	1, 2											
40	Brown-headed cowbird												

* = Cited reference makes a direct link with roads as a facilitator of the factor's effect. Cited references not marked by an asterisk establish the factor as a problem for the species but do not address whether roads facilitate the factor's effect.

^a Factors and effects listed here are defined in table 13. Factors and effects were documented from empirical literature and literature summaries, with each number listed below denoting a footnoted study. Presumed effects are denoted by a letter corresponding to a footnote that describes each presumed effect and cites the supporting literature related to other species of the taxa. A factor not marked with a number or letter (blank cells) indicates that we could find no research results on the factor in relation to the species or related taxa. Blank cells in this table therefore indicate no studies found rather than no effect of the factor.

A = Species depends on snags, down logs, or both structures to meet life requisites (Thomas and others 1979; volume 3, appendix 1, table 2); consequently, the species presumably is affected by a reduction in density of these structures and the documented links of this effect with roads (Hann and others 1997, Quigley and others 1996).

B = Species presumably responds negatively to openings or linear edges created by roads based on its dependence on closed-canopy habitats and lack of dependence on disturbed or contrasting habitats of openings and closed-canopy forests (such as "habitat-interior" species [Marcot and others 1994]); additional research is needed, however, to validate the presumption.

C = Factor is presumed to have a negative effect on the species based on documented effects of the factor on species of similar life history or taxa. For poaching or over-hunting of large mammals, documented effects include Cole and others (1997), Dood and others (1986), Knight and others (1988), McLellan and Shackleton (1988), Mech (1970), Scott and Servheen (1985), Stelfox (1971), and Yoakum (1978). For over-harvest and poaching of ground squirrels ("plinking"), effects are described by Ingles (1965). For collisions of reptiles with vehicles, documented effects are summarized by Vestjens (1973) and Bennett (1991). For roads as barriers to movements of small mammals, documented effects are described by Mader (1984), Swihart and Slade (1984), and Merriam (1989). For displacement of all taxa, documented effects are summarized by Bennett (1991). For any other effects on taxa marked with a "C" but not explicitly identified here, documented effects are summarized by Bennett (1991). Presumed effects of factors marked with a "C" require additional research to validate the presumption.

References:

- Hann and others 1997; 2. Quigley and others 1996; 3. Bock 1970; 4. Hodgman and others 1994; 5. Fortin and Cantin 1994; 6. Thompson 1994; 7. Nagorsen and Brigham 1993; 8. Idaho State Conservation Effort 1995; 9. Autenrieth 1978; 10. Coulter 1966; 11. Jones 1991; 12. Paragi and others 1994; 13. Scott and Servheen 1985; 14. Mace and others 1996; 15. Thurber and others 1994; 16. Mech 1970; 17. Van Ballenberghe and others 1975; 18. Mladenoff and others 1995; 19. Thiel 1985; 20. Fritts and others 1985; 21. Pletscher and others 1997; 22. Bangs and Fritts 1996; 23. Singer 1979; 24. Knight and others 1988; 25. McLellan and Shackleton 1988; 26. Dood and others 1986; 27. Yoakum 1978; 28. Kasworm and Manley 1990; 29. Mattson and others 1987; 30. Mattson and others 1992; 31. Bailey and others 1986; 32. Parker and others 1983; 33. Koehler and Brittell 1990; 34. ICBEMP 1996d; 35. ICBEMP 1996a; 36. Brown and others 1995; 37. Marti and Marks 1989; 38. Singer 1978; 39. Chadwick 1972; 40. Johnson 1983; 41. Joslin 1986; 42. Hamilton and others 1982; 43. Hicks and Elder 1979; 44. MacArthur and others 1979; 45. Bruns 1977; 46. Helms 1978; 47. Hornocker and Hash 1981; 48. Green and Anthony 1989; 49. Bechard and Schmutz 1995; 50. Lokemoen and Duebbert 1976; 51. Olendorff and Stoddart 1974; 52. Lanyon 1994; 53. Giesen and Connelly 1993; 54. Tirhi 1995; 55. Banci 1994; 56. Lehmkuhl and others 1997; 57. Geist 1971; 58. Moroz 1995; 59. USDA Forest Service and USDI Fish and Wildlife Service 1996; 60. Washington Department of Wildlife 1993b; 61. Yosef 1996; 62. Flickinger 1995; 63. DeStefano 1990; 64. Blumton 1989; 65. Stelfox 1971; 66. Taylor and others 1993; 67. Nussbaum and others 1983; 68. Copeland 1996; 69. Ehrlich and others 1988; 70. Mech 1973; 71. Tuttle 1988; 72. Frederick 1991; 73. Howard 1975; 74. Harmata 1981; 75. Gilmer and others 1985; 76. Clark 1975; 77. Holt 1992.

Shackleton 1988; Mech and others 1970; Scott and Servheen 1985; Stelfox 1971; Yoakum 1978). Roads facilitate poaching (Cole and others 1997).

4. Wolves and grizzly bears experience chronic, negative interactions with humans, and roads are a key facilitator of such interactions (Mace and others 1996, Mattson and others 1992, Thiel 1985). Repeated, negative interactions of these two species with humans increase mortality of both species and often cause high-quality habitats near roads to function as population sinks (Mattson and others 1996a, 1996b; Mech 1973).
5. Carnivorous mammals such as marten, fisher, lynx, and wolverine are vulnerable to over-trapping (Bailey and others 1986, Banci 1994, Coulter 1966, Fortin and Cantin 1994, Hodgman and others 1994, Hornocker and Hash 1981, Jones 1991, Parker and others 1983, Thompson 1994, Witmer and others 1998), and over-trapping can be facilitated by road access (Bailey and others 1986, Hodgman and others 1994, Terra-Berns and others 1997, Witmer and others 1998). Movement and dispersal of some of these species also are believed to be inhibited by high rates of traffic on highways (Ruediger 1996) but this belief has not been validated. Carnivorous mammals such as lynx also are vulnerable to increased mortality from highway accidents with motorized vehicles (as summarized by Terra-Berns and others 1997).
6. Reptiles seek roads for thermal cooling and heating, and in doing so, these species experience significant, chronic mortality from motorized vehicles (Vestjens 1973). Highways and other roads with moderate to high rates of motorized traffic may function as population sinks for many species of reptiles, thereby resulting in reduced population size and increased isolation of populations (Bennett 1991). For example, in Australia, 5 million reptiles and frogs are estimated to be killed annually by motorized vehicles on roads (Ehmann and Cogger 1985, as cited by Bennett 1991). Roads also facilitate human access into habitats for collection and killing of reptiles.
7. Many species are sensitive to harassment or human presence during particular seasons, which is often facilitated by road access; potential reductions in productivity, increases in energy expenditures, or displacements in population distribution or habitat use can occur (Bennett 1991, Mader 1984 Trombulak and Frissell 2000). Examples are human disturbance of leks (sage grouse and sharp-tailed grouse), of nests (raptors such as ferruginous hawk), and of dens (kit fox). Another example is elk avoidance of large areas near roads open to traffic (Lyon 1983, Rowland and others 2000), with the magnitude of elk avoidance increasing with rate of traffic (Wisdom and others 1999, Johnson and others 2000).
8. Bats are vulnerable to disturbance and displacement caused by human activities in caves, mines, and on rock faces (Hill and Smith 1984, Nagorsen and Brigham 1993). Cave or mine exploration and rock-climbing are examples of recreation that potentially reduce population fitness of bats that roost in these sites (Nagorsen and Brigham 1993, Tuttle 1988). Such activities may be facilitated by human developments and road access (Hill and Smith 1984).
9. Ground squirrels often are targets of recreational shooting ("plinking"), which is facilitated by human developments and road access (Ingles 1965). Most species of ground squirrels included in our analysis are local endemics; consequently, these small, isolated populations may be especially vulnerable to recreational shooting, potentially resulting in severe reductions or local extirpations of populations.
10. Roads often restrict the movements of small mammals (Mader 1984, Merriam and others 1988, Swihart and Slade 1984). Consequently, roads can function as barriers to population dispersal and movement of some species of small mammals (Oxley and Fenton 1974).
11. Many granivorous birds are attracted to grains and seeds along roadsides, thereby resulting in high mortality from vehicle collisions (Vestjens 1973). For example, pine siskins and white-winged crossbills are attracted to road salt, which can result in mortality from vehicle collisions (Ehrlich and others 1988).
12. Terrestrial vertebrates inhabiting areas near roads accumulate lead and other toxins that originate from motorized vehicles, with potentially lethal but largely undocumented effects (Bennett 1991).

In summary, no terrestrial vertebrate taxa appear immune to the myriad of road-associated factors that degrade habitat or that increase mortality. These multifaceted effects have strong management implications for landscapes characterized by moderate to high densities of roads, which is the typical pattern across large areas of the basin (figs. 21, 22). That is, about 51 percent of the basin supports road densities estimated as moderate, high, or extremely high (Quigley and others 1996). Specific implications of this pattern for species affected negatively by roads are as follows:

1. Source habitats likely are underused for many of the species listed in table 14 when such habitats exist in areas that contain moderate to high road density. In some cases, the presence of moderate or high densities of roads may index areas that function as population sinks and that would otherwise function as source environments if road density was low or zero.
2. Species listed in table 14 whose source habitats have undergone strong declines across the basin (see “Species-Level Results”, and “Group-Level Results,” this volume) may be affected in a synergistic manner by the combination of scarce or declining habitats and negative factors associated with roads. If this is true, our analysis of trends in source habitats underestimates the presumed effects of change in environmental conditions on such species and groups.
3. Mitigating the negative effects stemming from road-associated factors on the species listed in table 14 will be as challenging, or perhaps more challenging, than that of maintaining or restoring vegetation used as source habitats by these species. Mitigation will require effective control of human access and roads in relation to management of live-stock, timber, recreation, hunting, trapping, and mineral development. Mitigation will require intensive investments of money and resources that are sustained over long periods. Setting priorities for mitigation and implementing effective mitigative measures likely will require extensive, new research about species-road relations. Such research could be designed and conducted as joint management experiments between managers and researchers.

Mapping Road Density in Relation to Abundance of Source Habitats for Terrestrial Carnivores

Composite carnivore map of habitat abundance and road density—Subbasins having both zero to low road density and moderate to high abundance of source habitats for any of the four species of terrestrial carnivores (grizzly bear, gray wolf, wolverine, or lynx), considering current habitat abundance within each of the historical range of the species, were concentrated in seven distinct areas (fig. 23), identified as follows: area 1—the Greater Yellowstone Area, defined as subbasins within the eastern portion of the Snake Headwaters ERU; area 2—the Northern Continental Divide Area, centered within and adjacent to Glacier National Park and composed of subbasins within the extreme eastern portion of the Northern Glaciated Mountains ERU; area 3—the North Cascades Area, defined as the segment of North Cascades National Park that overlays one subbasin of the Northern Cascades ERU; area 4—the Bitterroot-Central Idaho Area whose subbasins overlap the Selway-Bitterroot Wilderness and the Frank Church River of No Return Wilderness within the Central Idaho Mountains ERU; area 5—the Eagle Cap Wilderness-Hells Canyon Area, composed of subbasins within the extreme eastern portion of the Blue Mountains ERU; area 6—the Owyhee Area, defined as subbasins within the southern half of the Owyhee Uplands ERU and southeast portion of the Northern Great Basin ERU; and area 7—the Crater Lake Area, composed of the portion of Crater Lake National Park that overlays one subbasin in the Upper Klamath ERU (fig. 23). Estimated habitat abundance for each carnivore species in relation to road density is summarized in the following sections and compared to the composite carnivore habitat-roads map of figure 23.

Grizzly bear—Subbasins having both zero to low road density and moderate to high abundance of source habitats for grizzly bear, considering current conditions within the historical range of the species (fig. 24), were concentrated in all seven areas that were identified on the composite carnivore habitat-roads map (compare fig. 24 with fig. 23). Interestingly, four of the seven areas—Greater Yellowstone, Continental Divide, North Cascades, and Bitterroot-Central Idaho—are within areas currently occupied by grizzly bear, or are within areas that have had occasional sightings or potential occurrences since 1970



Figure 21—Pixel-based predictions of road density classes within the basin (from Quigley and others 1996).



Figure 22—Generalized classes of road density estimated to dominate each subbasin. See “Methods”, “Summarizing Knowledge About Species-Road Relations,” for description of the steps used to estimate the dominant road class.



Figure 23—Seven areas composed of one or more subbasins that are dominated by zero to low road density and that also are dominated by moderate to high abundance of source habitats for either grizzly bear, gray wolf, wolverine, or lynx. Area number, name, and location are: area 1—Greater Yellowstone Area, defined as subbasins within the eastern portion of the Snake Headwaters ERU; area 2—Northern Continental Divide Area, centered within and adjacent to Glacier National Park and composed of subbasins within the extreme eastern portion of the Northern Glaciated Mountains ERU; area 3—North Cascades Area, defined as the segment of North Cascades National Park that overlays one subbasin of the Northern Cascades ERU; area 4—Bitterroot-Central Idaho Area whose subbasins overlap the Selway-Bitterroot Wilderness and the Frank Church River of No Return Wilderness within the Central Idaho Mountains ERU; area 5—Eagle Cap Wilderness-Hells Canyon Area, composed of subbasins within the extreme eastern portion of the Blue Mountains ERU; area 6—Owyhee Area, defined as subbasins within the southern half of the Owyhee Uplands ERU and southeast portion of the Northern Great Basin ERU; and area 7— Crater Lake Area, composed of the portion of Crater Lake National Park that overlays one subbasin in the Upper Klamath ERU.

(Mattson and others 1995). The other three areas—Eagle Cap Wilderness-Hells Canyon, Owyhee, and Crater Lake—have had no verified grizzly bear occurrences since early European settlement (late 1800s to early 1900s, Mattson and others 1995), although use of lower elevations within the Owyhee Area was probably incidental or infrequent.⁴

Also of interest is the fact that two other areas currently occupied by grizzly bear—the Selkirk and Cabinet-Yaak Ecosystems (Mattson and others 1995), each located within the portion of the Northern Glaciated Mountains ERU in northern Idaho and northwestern Montana—contain no subbasins having both moderate to high abundance of source habitats and zero to low road density (fig. 24). Consequently, these areas were not detected by our mapping criteria. That is, all subbasins within the Selkirk and Cabinet-Yaak Ecosystems have low abundance of source habitats, moderate to high road density, or both (fig. 24). Although our mapping criteria did not detect these two areas, it is noteworthy that the Selkirk and Cabinet-Yaak ecosystems are believed to contain less than 20 grizzly bears (Knick and Kasworm 1989, Wielgus and Bunnell 1995). The relatively small number of bears present in these ecosystems suggests that environmental conditions may not be as conducive to maintenance of self-sustaining bear populations as would other areas of the basin that we identified with our mapping criteria.

Gray wolf—Subbasins having both zero to low road density and moderate to high abundance of source habitats for gray wolf, considering current conditions within the historical range of the species, were concentrated in five areas: Greater Yellowstone, Continental Divide, Bitterroot-Central Idaho, Owyhee, and Eagle Cap Wilderness-Hells Canyon (compare fig. 25 with fig. 23). Three of these same areas used by grizzly bear—Greater Yellowstone, Continental Divide, and Bitterroot-Central Idaho—also are currently occupied by wolf (USDI Fish and Wildlife Service 1997). The other two areas—Eagle Cap Wilderness-Hells Canyon and Owyhee—have had no verified wolf occurrences since early European settlement (USDI Fish and

Wildlife Service 1987) and, in contrast to the other three areas, have not benefitted from translocation programs or from immigration of wolves from areas outside the basin (USDI Fish and Wildlife Service 1997). However, recent sightings of radio-collared wolves (from Idaho) in the Blue Mountains ERU suggest that the Eagle Cap Wilderness-Hells Canyon Area may already be used by some wolves at least seasonally.

Wolverine—Subbasins having both zero to low road density and moderate to high current abundance of source habitats for wolverine, considering all areas within the historical range of the species, were concentrated in the Greater Yellowstone, Northern Continental Divide, North Cascades, Bitterroot-Central Idaho, Eagle Cap Wilderness-Hells Canyon, and Crater Lake Areas (compare fig. 26 with fig. 23). Interestingly, all six of these areas have had verified occurrences of wolverine since 1961, based on mapped observations by Maj and Garton (1994). The largest concentration of these occurrences appears to be within the Bitterroot-Central Idaho Area, based on an overlay of fig. 26 with Maj and Garton's (1994) 1961-93 maps of wolverine observations (Wisdom 2000).

Also of interest is the fact that >90 percent of the wolverine observations compiled by Maj and Garton (1994) for 1961-93 encompass subbasins containing moderate to high abundance of the source habitats of this species (Wisdom 2000). Moreover, <10 percent of these verified wolverine observations were located in subbasins containing low abundance of source habitats. This high concentration of wolverine observations in relation to subbasins having moderate to high abundance of wolverine source habitats also is congruent with areas of the basin that likely have higher potential to support reproductive den sites (per descriptions of Copeland [1996] and Magoun and Copeland [1998]).

Lynx—The map for lynx (fig. 27) was similar to that for wolverine (fig. 26). That is, the same five areas—Greater Yellowstone, Northern Continental Divide, North Cascades, Bitterroot-Central Idaho, and Eagle Cap Wilderness-Hells Canyon—contained the only subbasins having both moderate to high habitat abundance and zero to low road densities (compare fig. 27 with fig. 23). The sixth area identified for wolverine—Crater Lake—was assumed to be outside the geographic

⁴ Personal communication. 1998. David Mattson, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center and Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844-1136.



Figure 24—Low, moderate, and high abundance of source habitats for grizzly bear in relation to zero and low road densities for each of 164 subbasins in the interior Columbia basin.



Figure 25—Low, moderate, and high abundance of source habitats for gray wolf in relation to zero and low road densities for each of 164 subbasins in the interior Columbia basin.



Figure 26—Low, moderate, and high abundance of source habitats for wolverine in relation to zero and low road densities for each of 164 subbasins in the interior Columbia basin.



Figure 27—Low, moderate, and high abundance of source habitats for lynx in relation to zero and low road densities for each of 164 subbasins in the interior Columbia basin.

range of the lynx (Marcot and others, in prep.). A more recent summary of occurrence data (McKelvey and others 1999), suggests, however, that lynx occur in portions of the southern Cascades of Oregon outside the range map of Marcot and others (in prep.).

In contrast to wolverine, most verified lynx locations, based on combined data from Maj and Garton (1994) and Lewis and Wenger (1998), corresponded to subbasins having a high abundance of lynx source habitats, regardless of road density (Wisdom 2000). That is, lynx locations verified by Maj and Garton (1994) from 1961 to 1993 and by Lewis and Wenger (1998) from 1977 to 1998 corresponded closely to subbasins of high abundance of source habitats rather than to subbasins having both zero to low road density and moderate to high habitat abundance. Similar results were found when lynx locations of McKelvey and others (1999) were overlaid in relation to our subbasin maps of lynx habitat abundance and road density (Wisdom 2000).

Management implications—Several interesting patterns emerged from the overlays of road density with current habitat abundance for grizzly bear, wolf, wolverine, and lynx, especially when current or recent occurrence data for all four species was considered. First, most of the subbasins having both moderate to high abundance of source habitats and zero to low road density occurred within or adjacent to National Parks or Wilderness Areas. Second, most of these subbasins occurred within areas of high elevation. Third, most of these subbasins were identified within areas currently occupied by most or all of the four species. Two other areas, however, currently occupied by grizzly bear—the Selkirk and Cabinet-Yaak Ecosystems (Mattson and others 1995)—were not identified by our mapping exercise because subbasins within these areas had low abundance of source habitats, moderate to high road density, or both (fig. 24). And finally, the pattern of lynx observations corresponded more closely to subbasins of high habitat abundance rather than to subbasins identified by our mapping criteria.

Although these patterns are interesting and often agreed in general terms with knowledge of habitat requirements and known occurrences of all four species, our maps are strictly qualitative and not validated through formal research. As such, our maps should be considered working hypotheses that must be tested as part of large-scale studies that evaluate

a range of environmental conditions in relation to rigorous surveys of the presence and absence of each species. Such an evaluation has been proposed for lynx (Ruggiero and others 1999) and similar evaluations have occurred for wolf and grizzly bear in parts of the basin (e.g., Merrill and others [1999] for grizzly bear and evaluations described by Bangs and Fritts [1996] for gray wolf). Notably missing are any large-scale evaluations for wolverine or more comprehensive evaluations for wolf or grizzly bear that encompass the entire basin and adjacent ecosystems. Such evaluations are needed to corroborate the patterns displayed in our maps and to elucidate more fine-scale relations between environmental conditions and the likelihood of population occurrence for all four species.

Given these limitations, our maps could be useful to managers when considered in tandem with other large-scale data on wolf, grizzly bear, wolverine, and lynx. The mapping pattern shown here illustrates an especially important point for all four species: that large areas of the basin composed of moderate or high abundance of source habitats may not be used, or may be underused, by many or all of the four species, presumably because of negative interactions with humans that are facilitated by roads and human developments. For gray wolf and grizzly bear, researchers have verified a strong, negative relation between road density and population fitness (e.g., Mace and others 1996, Mattson and others 1996b, Mech and others 1988, Thiel 1985). Similar relations have been hypothesized for wolverine and lynx within the basin (ICBEMP 1996b, 1996c), and limited research on lynx (Bailey and others 1986 and as summarized by Terra-Berns and others 1997) outside the basin supports the hypothesis that population fitness is lower in areas characterized by increased road access. Because of these observed or suspected effects on population fitness, our maps identified a handful of large areas of abundant source habitats that have low road density. Presumably these areas have higher potential to support populations that could persist without additive mortality that may be caused by road-associated factors. Thus, managers interested in conserving the few large blocks of remaining habitats that are relatively secure from human disturbances for terrestrial carnivores would want to focus on maintenance and improvement of the seven areas identified in our analysis (fig. 23), particularly the Greater Yellowstone, Continental Divide, North Cascades, and Bitterroot-Central Idaho Areas. These areas could be effective

“building blocks” from which an overall network of habitat and human activity strategies could be devised to ensure a high probability of well-distributed, persistent populations of all four species in the basin.

Validating Agreement Between Change in Source Habitats and Expert Opinion-Based Habitat Outcomes

Direction of change (historical to current) in source habitats agreed 81 to 84 percent of the time with a like direction of change in historical to current habitat or cumulative effects outcomes (Lehmkuhl outcomes) for 68 of our broad-scale species of focus that also were evaluated by Lehmkuhl and others (1997). The consistency of agreement between our trends in source habitats and the Lehmkuhl outcomes reflected strong, underlying congruity; this was true for habitat trends in relation to the habitat outcomes, as well as to the cumulative effects outcomes, for both the Eastside EIS and the Upper Columbia River EIS areas.

Thirteen species, however, had trends in source habitats that differed in direction from either the habitat or the cumulative effects outcomes (table 15). Trends in source habitats versus the Lehmkuhl outcomes generally differed for one of two reasons: (1) the expert panels for Lehmkuhl and others (1997) considered fine-scale characteristics of habitat, such as snag abundance, riparian features, or habitat patchiness, that we could not address with the large pixel size (100 ha [247 ac]) used for our source habitat analysis; or (2) the expert panels for Lehmkuhl and others (1997) considered effects of roads or other nonvegetative factors that we did not consider in our source habitat analysis. These two differences in evaluation criteria potentially account for contradictions in direction in trends of source habitats versus outcomes for 10 of the 13 species listed in table 15. For example, the expert panels for Lehmkuhl and others (1997) cited fine-scale habitat features as the primary basis for evaluating 8 of the 13 species, and cited roads or other nonvegetative features, as the primary basis for evaluating 2 other species. When these 10 species are removed from the analysis, the direction of change in source habitats versus the direction of change in the Lehmkuhl outcomes agreed 95 to 97 percent of the time.

Although such high agreement between source habitat trends and the Lehmkuhl outcomes is compelling, it is not unexpected for at least two reasons. One is the overlap (at least 25 percent) that existed between experts who served on the panels of Lehmkuhl and others (1997) and the experts who served on our panels that identified source habitats; experts serving on both panels would be expected to identify source habitats in the same manner in which they based their outcome projections. A second reason is that most species experts tend to agree on the habitat factors and effects that contribute to population persistence, and all of these experts draw from the same set of empirical knowledge, regardless of overlap in experts serving on both panels.

Nonetheless, the congruity between trends in source habitats and those found in Lehmkuhl and others (1997), although strictly correlative, indicates that direction of change in source habitats reflects a like direction of change in projected, long-term population persistence for any given species. That is, species whose source habitats underwent a strong decline from historical to current periods also should be expected to have an estimated lower likelihood of population persistence currently than historically. Moreover, a strong decline in source habitats presumably contributes largely or wholly to the reduced likelihood of population persistence, based on empirical knowledge conveyed by the experts. These final points are important to Federal managers who must demonstrate compliance with viability requirements of ESA, NFMA, and related laws. Given the congruity of results presented here, it seems that our methods of analyzing trends in source habitats may be useful in analyzing future habitat scenarios for EIS alternatives in terms of compliance with Federal viability requirements.

Major Findings and Implications

1. Source habitats for most species declined strongly from historical to current periods across large areas of the basin. Strongest declines were for species dependent on low-elevation, old-forest habitats (family 1), for species dependent on combinations of rangelands or early-seral forests with late-seral forests (family 8), and for species dependent on

Table 15—Species for which trends in source habitats differed from habitat outcomes of Lehmkuhl and others (1997)

Common name	Relative change in source habitats	Change in habitat outcome	Reasons for habitat outcome (from panel notes)	Most likely reasons for difference
Vaux's swift	-7.99	Increase	Increase in habitat due to fire suppression and subsequent increase in grand-fir, which provides source habitat for this species	Although grand fir did increase in some areas, when considering all source habitats for Vaux's swift, habitat declined slightly basin-wide.
Fringed myotis	17.36	Decrease	Loss of large snags and increased human disturbance	We did not evaluate change in snag abundance or the effects of human disturbance.
Long-legged myotis	17.16	Decrease	Loss of large snags	We did not evaluate changes in snag abundance.
Three-toed woodpecker	22.44	Decrease	Loss of snags	We did not evaluate changes in snag abundance.
Mountain quail	16.09	Decrease	Reduction in riparian shrub cover and species composition due to grazing	We did not analyze the fine-scale attributes of riparian habitats.
Black-chinned hummingbird	14.37	Decrease	Fire suppression has reduced amount of openings, and there has been an increase in fragmentation of riparian areas	We did not evaluate patchiness of habitats or fine-scale riparian attributes.
Olive-sided flycatcher	17.55	Decrease	Fire suppression has reduced patchiness of late- and early-seral habitat, and important pine habitat	We did not evaluate patchiness of habitats.
Lynx	14.49	Decrease	Overtrapping and negative effects of logging on prey habitat juxtaposition	Our evaluation did not include effects of trapping or patchiness of habitats.
Wolverine	14.41	Decrease	Roads and human disturbance	Our evaluation did not explicitly measure road effects or other nonvegetative factors.

**Table 15—Species for which trends in source habitats differed from habitat outcomes of Lehmkuhl and others (1997)
(continued)**

Common name	Relative change in source habitats	Change in habitat outcome	Reasons for habitat outcome (from panel notes)	Most likely reasons for difference
Striped whipsnake	-20.59	No change on BLM/FS Eastside lands	Population has not declined on Eastside BLM and FS lands because these lands have not undergone the increase in agricultural development and dam construction as have the private lands or Upper Columbia River Basin BLM and FS lands	Basin-wide, the habitat outcome score of a negative change matches the decline in source habitat.
Sharptail snake	55.23	Decrease	Always patchy distribution, but situation has declined due to agriculture and urban development, and perhaps climate change	Our analysis did not measure changes in overall population distribution from historical that the panelists estimated.
Mojave black-collared lizard	-3.14	No change in Upper Columbia River Basin CumEff	Habitat has become more fragmented, and has declined due to agriculture, non-native vegetation, invasion of exotics, and reservoir development	Most of species range is on BLM-administered lands, which did show a decline in habitat outcome. Although there was no change in the weighted mean score, the distribution of habitat outcome scores was lower in the historical period.
White-winged crossbill	-46.41	No change	Nomadic species associated with spruce, higher elevation forests. Species not negatively affected by the increased fragmentation caused by relatively small amounts of logging of that habitat.	Unknown, though source habitats include both upper and lower montane late-seral forests, which did decline basin-wide.

native grassland and open-canopy sagebrush habitats (family 12). Widespread but less severe declines also occurred for most species dependent on old-forest habitats present in several elevation zones (family 2); for species dependent on early-seral forests (family 4); for species dependent on native herbland, shrubland, and woodland habitats (family 10); and for species dependent on native sagebrush habitats (family 11). Source habitats for all of the above-named families have become increasingly fragmented, simplified in structure, and infringed on or dominated by exotic plants.

2. Primary causes for decline in old-forest habitats (families 1 and 2) are intensive timber harvest and large-scale fire exclusion (Hann and others 1997). Additional causes for decline in low-elevation, old-forest habitats are conversion of land to agriculture and to residential or urban development (Hann and others 1997). These same causes—intensive timber harvest and large-scale fire exclusion—also are primarily responsible for the large decline in early-seral habitats (family 4).
3. Primary causes for decline in native herbland, woodland, grassland, and sagebrush habitats (families 10, 11, and 12) are excessive livestock grazing, invasion of exotic plants, and conversion of land to agriculture and residential and urban development (Hann and others 1997). Altered fire regimes also are responsible for decline in native grassland and shrubland habitats.
4. Various road-associated factors negatively affect habitats or populations of most species analyzed here. Effects of road-associated factors can be direct, such as habitat loss and fragmentation because of road construction and maintenance. Effects also can be indirect, such as displacement or increased mortality of populations in areas near roads in relation to motorized traffic and associated human activities. Because of the high density of roads present across large areas of the basin, effects from road-associated factors must be considered additive to that of habitat loss. Moreover, it is likely that many habitats are underused by several species because of the effects of roads and associated factors; this may be especially true for species of carnivorous mammals, particularly gray wolf and grizzly bear.
5. Implications of our results for managing old-forest structural stages include the potential to conserve old-forest habitats in subbasins and watersheds where decline has been strongest; manipulate mid-seral forests to accelerate development of late-seral stages where such manipulations can be done without further reduction in early- or late-seral forests; and restore fire and other disturbance regimes in all forested structural stages to hasten development and improvement in the amount, quality, and distribution of old-forest stages. Many of the practices designed to restore old-forest habitats also can be designed to restore early-seral habitats. For example, long-term restoration of more natural fire regimes will hasten development of both early- and late-seral structural conditions, and minimize area of mid-seral habitats, which few if any species depend on as source habitat.
6. Implications of our results for managing rangelands include the potential to conserve native grasslands and shrublands that have not undergone large-scale reduction in composition of native plants; control or eradicate exotic plants on native grasslands and shrublands where invasion potential or spread of exotics is highest; and restore native plant communities, by using intensive range practices, where potential for restoration is highest. Restoration includes the potential to manipulate livestock grazing systems and stocking rates where existing or past grazing practices have contributed to the decline in native grasslands and shrublands.
7. Implications of our summary of road-associated effects include the potential to mitigate a diverse set of negative factors associated with roads. Comprehensive mitigation of road-associated factors would require a substantial reduction in the density of existing roads as well as effective control of road access in relation to management of livestock, timber, recreation, hunting, trapping, mineral development, and other human activities. Efforts to restore habitats without simultaneous efforts to reduce road density and control human disturbances will curtail the effectiveness of habitat restoration, or even contribute to its failure; this is because the large number of species that are simultaneously affected by decline in habitat as well as by road-associated factors.

8. Implications of all our results, when considered at multiple spatial scales ranging from the basin, ERU, subbasin, and watershed, provide spatially explicit opportunities for conservation and restoration of source habitats across various land ownerships and jurisdictions. Moreover, our results provide temporally explicit opportunities for design of long-term efforts to restore source habitats that have undergone strong, widespread decline, with simultaneous design of efforts to conserve these same habitats where they exist currently. Use of our findings to conduct effective spatial and temporal prioritization of restoration and conservation efforts for terrestrial species and habitats represents a major opportunity for resources managers in the basin.

Acknowledgments

The former and current staff of the ICBEMP, particularly Kathy Campbell, Heidi Bigler Cole, Jodi Clifford, Cindy Dean, Connie Gilbreath, Lisa Meabon, Deanna Mendiola, Eloisa Munden, LaVerne Scott, Cathy Wiese, and John Zodnick, provided essential technical and administrative support for our work. Becky Gravenmier, Arthur Miller, Carolyn McCarthy, and Cary Lorimar of the ICBEMP's data management and GIS staff, and Kim Jones of the Umatilla National Forest, produced all map-based figures for our document. Terry Locke, data management and GIS staff, and Becky Gravenmier provided essential support for data management.

We are indebted to the many professionals who conducted literature reviews, collections, and summaries. Kevin Lair, Wildlife Biology Program, University of Montana, conducted the initial literature search. Staff of the USDA Forest Service North Central Research Station, particularly Syble Thon and Laura Hutchinson, directed the extensive work needed to obtain and copy the large body of literature used in our paper. Syble Thon also formatted and edited our references to PNW style. The following biologists conducted the literature summaries: Quinn Carver, Helena National Forest; Kate Boula, Umatilla National Forest; Denise Washick, Nez Perce National Forest; Amy Jacobs, Flathead National Forest; Ralph Anderson, Wallowa-Whitman National Forest; Camryn Lee, Wenatchee Forest Sciences Laboratory; J.T. Stangl, Gallatin National Forest; Jim Sparks, Gallatin National Forest;

Stephen Carter, Wenatchee National Forest; Keith Kistler, Wenatchee National Forest; Fara Currim, Gifford Pinchot National Forest; Fred Higgenbotham, Umatilla National Forest; and Karen Haines, Malheur National Forest. Nancy Warren, Flathead National Forest, organized and directed the work of the biologists who conducted the literature summaries. Nancy's contribution to this work was essential to its successful completion.

Jeff Jones, Sherm Karl, and Paul Hessburg, members of the ICBEMP's landscape ecology science team, provided invaluable advice and consultation about vegetation dynamics and landscape ecology of the basin. Tom Quigley provided critical administrative support and technical direction to our team; without Tom's direction and support, our work would not have been possible. Alan Sands, then of BLM in Boise, was an early member of our team and helped provide initial direction for our work. Other early members of our team who helped with initial work were Fred Samson, USDA Forest Service Region 1, and Dave Newhouse, an employee of USDA Forest Service, Region 4, at the time of the work.

Detailed and effective technical reviews were provided by Martin Raphael, Kim Mellen, Charles Meslow, Reed Noss, Alan Sands, Becky Gravenmier, Jeff Jones, Fred Way, and Camryn Lee. Dave Turner, Station Statistician, USDA Forest Service, Rocky Mountain Research Station, reviewed the document for methods and interpretations of statistical analyses. Jodi Clifford provided helpful and thorough editing of drafts for clarity, diction, and grammar, and helped format all tables and figures to needed style requirements.

Abbreviations

Centimeter	(cm)
Hectare	(ha)
Inch	(in)
Kilometer	(km)
Meter	(m)
Mile	(mi)
Year	(yr)

References

- Anon. 1996.** Sierra Nevada Ecosystem Project. Davis, CA: University of California-Davis; final report to Congress; Centers for Water and Wildland Resources report 38. [Irregular pagination].
- Alverson, William S.; Kuhlmann, Walter; Waller, Donald M. 1994.** Wild forests: conservation biology and public policy. Washington, DC: Island Press. 300 p.
- Autenrieth, R. 1978.** Guidelines for the management of pronghorn antelope. In: Proceedings of the 8th biennial pronghorn antelope workshop; 1978 May 2-4; Jasper, AB. Jasper, AB: Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division: 472-525.
- Bailey, T.N.; Bangs, E.E.; Portner, M.F. [and others]. 1986.** An apparent overexploited lynx population on the Kenai Peninsula, Alaska. *Journal of Wildlife Management*. 50: 279-290.
- Banci, Vivian. 1994.** Wolverine. In: Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W. [and others], tech. eds. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the Western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 7-37. Chapter 2.
- Bangs, Edward E.; Fritts, Steven H. 1996.** Reintroducing the gray wolf to central Idaho and Yellowstone National Park. *Wildlife Society Bulletin*. 24(3): 402-413.
- Barclay, R.M.R. 1991.** Population structure of temperate zone insectivorous bats in relation to foraging behavior and energy demand. *Journal of Animal Ecology*. 60: 165-178.
- Bashore, T.L.; Tzilkowski, W.M.; Bellis, E.D. 1985.** Analysis of deer-vehicle collision sites in Pennsylvania. *Journal of Wildlife Management*. 49: 769-774.
- Bechard, M.J.; Schmutz, J.K. 1995.** Ferruginous hawk (*Buteo regalis*). In: Poole, A.; Gill, F., eds. The birds of North America. No. 172. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 20 p.
- Beck, Jonathan M.; Peterson, Charles R. 1995.** Movements and habitat selection of the longnose snake (*Rhinocheilus lecontei*) in southwestern Idaho. Tech. Bull. 95-18. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office. 30 p.
- Belnap, J. 1995.** Surface disturbances: their role in accelerating desertification. *Environmental Monitoring and Assessment*. 37: 39-57.
- Belnap, Jayne. 1993.** Recovery rates of cryptobiotic crusts: inoculant use and assessment methods. *Great Basin Naturalist*. 53: 89-95.
- Belnap, Jayne; Gardner, John S. 1993.** Soil microstructure in soils of the Colorado Plateau: the role of the cyanobacterium *Microcoleus vaginatus*. *Great Basin Naturalist*. 53: 40-47.
- Bennett, A.F. 1991.** Roads, roadsides and wildlife conservation: a review. In: Saunders, D.A.; Hobbs, R.J., eds. Nature conservation 2: the role of corridors. Victoria, Australia: Surrey Beatty and Sons: 99-118.
- Blumton, A.K. 1989.** Factors affecting loggerhead shrike mortality in Virginia. Blacksburg, VA: Virginia Polytechnical Institute and State University. 85 p. M.S. thesis.

- Boarman, William I.; Sazaki, Marc. 1996.** Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. In: Evink, G.; Garrett, P.; Berry, J., eds. Proceedings, transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors; 1996, April 3-May 2; Orlando, FL: Department of Transportation, Federal Highway Administration: 169-173.
- Bock, C.E.; Webb, B. 1984.** Birds as grazing indicator species in southeastern Arizona. *Journal of Wildlife Management*. 48(3): 1045-1049.
- Bock, Carl E.; Lepthien, L.W. 1976.** Synchronous eruptions of boreal seed-eating birds. *American Naturalist*. 110: 559-579.
- Brennan, L.A. 1990.** What happened to the mountain quail in Idaho? *Quail Unlimited*. 9: 42-43, 69.
- Brennan, Leonard A. 1989.** Report on a survey of mountain quail in eastern Oregon, southeastern Washington, western Idaho, and northern Nevada. Boise, ID: The Chukar Foundation. 58 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Brennan, L.A.; Block, W.M.; Gutierrez, R.J. 1987.** Habitat use by mountain quail in northern California. *Condor*. 89: 66-74.
- Brown, Herbert A.; Bury, R. Bruce; Darda, David M. [and others]. 1995.** Reptiles of Washington and Oregon. Seattle, WA: Seattle Audubon Society. 176 p.
- Bruns, E.H. 1977.** Winter behavior of pronghorns in relation to habitat. *Journal of Wildlife Management*. 41(3): 560-571.
- Busack, Stephen D.; Bury, R. Bruce. 1974.** Some effects of off-road vehicles and sheep grazing on lizard populations in the Mojave Desert. *Biological Conservation*. 6: 179-183.
- Carbyn, L.N.; Patriquin, D. 1983.** Observations on home range sizes, movements and social organization of lynx (*Lynx canadensis*) in Riding Mountain National Park, Manitoba. *Canadian Field-Naturalist*. 97: 262-267.
- Cassirer, E. Frances; Oldenburg, Lloyd E.; Coggins, Victor L. [and others]. 1996.** Overview and preliminary analysis of a bighorn sheep dieoff, Hells Canyon 1995-96. In: Proceedings of the 10th biennial symposium. Northern wild sheep and goat council; 1996 April 29-May 3; Silverthorne, CO. Thermopolis, WY: Northern Wild Sheep and Goat Council. 10: 78-86.
- Chadwick, Douglas H. 1972.** Mountain goat ecology—logging relationships in the Bunker Creek drainage of western Montana. State of Montana; Project No. W-120-R3, No. 91.1; big game research, final job report. 228 p. On file with: U.S. Department of Agriculture; Agricultural Research Service, National Agricultural Library, 10301 Baltimore Blvd., Beltsville, MD 20705-2351. Record no. 20722.
- Christensen, A.G.; Lyon, L.J.; Lonner, T.N., comps. 1991.** Proceedings of a symposium on elk vulnerability; 1991 April 10-12; Bozeman, MT. Bozeman, MT: Montana Department of Fish, Wildlife, and Parks, Montana State University. 330 p.
- Clark, Richard J. 1975.** A field study of the short-eared owl, *Asio flammeus* (Pontoppidan), in North America. *Wildlife Monographs*. 47: 1-67.

- Coggins, V.L. 1988.** The Lostine Mountain bighorn sheep die-off and domestic sheep. Proceedings of the biennial symposium of the Northern Wild Sheep and Goat Council. 6: 66-76.
- Cole, E.K.; Pope, M.D.; Anthony, R.G. 1997.** Effects of road management on movement and survival of Roosevelt elk. *Journal of Wildlife Management*. 61: 1115-1126.
- Conroy, Michael J.; Cohen, Yosef; Frances, James C. [and others]. 1995.** Parameter estimation, reliability, and model improvement for spatially explicit models of animal populations. *Ecological Applications*. 5(1): 17-19.
- Conroy, Michael J.; Noon, Barry R. 1996.** Mapping of species richness for conservation of biological diversity: conceptual and methodological issues. *Ecological Applications*. 6(3): 763-773.
- Copeland, Jeffrey P. 1996.** Biology of the wolverine in central Idaho. Moscow, ID: University of Idaho. 138 p. M.S. thesis.
- Coulter, M.W. 1966.** Ecology and management of fishers in Maine. Syracuse, NY: Syracuse University, College of Forestry. 183 p. Ph.D. dissertation.
- Craig, R.B. 1978.** An analysis of the predatory behavior of the loggerhead shrike. *Auk*. 95(2): 221-234.
- Daubenmire, R. 1970.** Steppe vegetation of Washington. *Bull.* 62. Pullman, WA: State of Washington, Agricultural Experiment Station. 131 p.
- DeStefano, Stephen. 1990.** Investigation of the status of kit foxes in southeastern Oregon. Tech. Rep. 90-5-01. Portland, OR: Oregon Department of Fish and Wildlife, Wildlife Diversity Program. 60 p.
- Dood, Arnold R.; Brannon, Robert D.; Mace, Richard D. 1986.** Final programmatic environmental impact statement: the grizzly bear northwestern Montana. Helena, MT: Montana Department of Fish, Wildlife, and Parks. 287 p.
- Dood, Arnold R.; Brannon, Robert D.; Mace, Richard D. 1985.** Management of grizzly bears in the northern continental divide ecosystems, Montana. *Transactions of the 51st North American Wildlife and Natural Resources Conference*. 51: 162-177.
- Doyle, F.I.; Smith, J.M.N. 1994.** Population responses of northern goshawks to the 10-year cycle in numbers of snowshoe hares. *Studies in Avian Biology*. 16: 122-129.
- Easter-Pilcher, Andrea. 1996.** Implementing the Endangered Species Act: assessing the listing of species as endangered or threatened. *BioScience*. 46(5): 355-363.
- Ehmann, H.; Coggar, H. 1985.** Australia's endangered herpetofauna: a review of criteria and politics. In: Green, G.; Shine, R.; Ehmann, H., eds. *Biology of Australian frogs and reptiles*. Sydney, Australia: Surrey Beatty and Sons and Royal Zoological Society of New South Wales: 435-447.
- Ehrlich, Paul R.; Dobkin, David S.; Wheye, Darryl. 1988.** *The birder's handbook*. New York: Simon and Schuster. 785 p.
- Eidenshink, J. 1992.** The conterminous U.S. AVHRR data set. *Photogrammetric Engineering and Remote Sensing*. 58(6): 809-813.

- Flather, C.H.; Joyce, L.A.; Bloomgarden, C.A. 1994.** Species endangerment patterns in the United States. Gen. Tech. Rep. RM-GTR-241. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 42 p.
- Flather, Curtis H.; Knowles, Michael S.; Kendall, Iris A. 1998.** Threatened and endangered species geography: characteristics of species hotspots in the conterminous United States. *BioScience*. 48(5): 365-376.
- Flickinger, E.L. 1995.** Loggerhead fatalities on a highway in Texas. In: Yosef, R.; Lohrer, F.E., eds. Shrikes (Laniidae) of the world: biology and conservation: 1st international shrike symposium; 1993 January 11-15; Lake Placid, FL. In: Proceedings of the Western Foundation of Vertebrate Zoology; 6(1): 67-69.
- Foreyt, William J. 1994.** Effects of controlled contact exposure between healthy bighorn sheep and llamas, domestic goats, mountain goats, cattle, domestic sheep, or mouflon sheep. In: Proceeding of the 9th biennial symposium. Northern Wild Sheep and Goat Council; 1994 May 2-6; Cranbrook, BC. Thermopolis, WY: Northern Wild Sheep and Goat Council. 9: 7-14.
- Foreyt, William J.; Jessup, David A. 1982.** Fatal pneumonia of bighorn sheep following association with domestic sheep. *Journal of Wildlife Diseases*. 18: 163-168.
- Forman, Richard T.T. 1995.** Land mosaics: the ecology of landscapes and regions. Cambridge, England: Cambridge University Press. 325 p.
- Forman, Richard T.T. 2000.** Estimate of area affected ecologically by the road system in the United States. *Conservation Biology*. 14: 31-35.
- Forman, Richard T.T.; Hersperger, Anna M. 1996.** Road ecology and road density in different landscapes, with international planning and mitigation solutions. In: Evink, G.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. Proceedings of a symposium; 1996 April 3-May 2; Orlando, FL: Department of Transportation, Federal Highway Administration: 1-23.
- Forman, Richard T.T.; Friedman, Debras S.; Fitzhenry, David [and others]. 1997.** Ecological effects of roads: toward summary indices and an overview of North America. In: Canters, Kees, ed. Proceedings, international conference on habitat fragmentation, infrastructure, and the role of ecological engineering: 1995 September 12-17; Maastricht and The Hague, The Netherlands. [The Netherlands]: Ministry of Transport, Public Works, and Water Management: 40-54.
- Fortin, C.; Cantin, M. 1994.** The effects of trapping on a newly exploited American marten population. In: Buskirk, S.W.; Harestad, A.S.; Raphael, M.G.; Powell, R.A., eds. Martens, sables, and fishers: biology and conservation. Ithaca, NY: Cornell University Press: 179-191.
- Fraser, D. 1979.** Sightings of moose, deer, and bears on roads in northern Ontario. *Wildlife Society Bulletin*. 7: 181-184.
- Frederick, Glenn P. 1991.** Effects of forest roads on grizzly bears, elk, and gray wolves: a literature review. Publ. R1-91-73. Libby, MT: Kootenai National Forest. 53 p.
- Fritts, Steven H.; Paul, William J.; Mech, L. David. 1985.** Can relocated wolves survive? *Wildlife Society Bulletin*. 13: 459-463.

- Gibilisco, Chuck; Heinemeyer, K.S.; Jones, Jeff; Mack, Curt. 1995.** Conservation strategy for fisher (*Martes pennanti*) and marten (*Martes americana*) in Idaho. In: Idaho Department of Fish and Game, Nez Perce Tribe, and Sawtooth National Forest. Forest carnivores in Idaho. Habitat Idaho State Conservation Effort; Idaho Department of Fish and Game, Idaho Department of Parks and Recreation; U.S. Department of the Interior, Bureau of Land Management; U.S. Department of Agriculture, Forest Service, Northern and Intermountain Regions; U.S. Department of the Interior, Fish and Wildlife Service: 43-70. Draft report dated April 21, 1995. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, USDA Forest Service, 304 N. 8th Street, Boise, ID 83702.
- Giesen, K.M.; Connelly, J.W. 1993.** Guidelines for management of Columbian sharp-tailed grouse habitats. Wildlife Society Bulletin. 21(3): 325-333.
- Geist, Valerius. 1971.** Mountain sheep: a study in behavior and evolution. Chicago: The University of Chicago Press. 383 p.
- Gilmer, D.S.; Evans, D.L.; Konrad, P.M.; Stewart, R.E. 1985.** Recoveries of ferruginous hawks banded in south-central North Dakota. Journal of Field Ornithology. 56: 184-187.
- Gravenmier, Rebecca A.; Wilson, Andrew; Steffenson, John. 1997.** Information system development and documentation. In: Quigley, Thomas M.; Arbelbide, S.J., tech. eds. An assessment of ecosystem components in the interior Columbia basin including portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 2012-2066. Vol. 4. Chapter 8. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Green, G.A.; Anthony, R.G. 1989.** Nesting success and habitat relationships of burrowing owls in the Columbia basin, Oregon. Condor. 91(2): 347-354.
- Griffin, Daude N. 1959.** The poisoning of meadowlarks with insecticides. Wilson Bulletin. 71(2): 193.
- Hamilton, K.S.; Holl, S.K.; Douglas, C.L. 1982.** An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel Mountains, California. Transactions of the Annual Meeting of the Desert Bighorn Council. 26: 50-55.
- Hann, Wendel J.; Jones, Jeffrey L.; Karl, Michael G. [and others]. 1997.** Landscape dynamics of the basin. In: Quigley, Thomas M.; Arbelbide, S.J., tech. eds. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 337-1055. Vol. 2. Chapter 3. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Hann, Wendel J.; Jones, Jeffrey L.; Keane, Robert E. [and others]. 1998.** Landscape dynamics. Journal of Forestry. 96(10): 10-15.
- Hansen, A.J.; Garmon, S.L.; Marks, B. 1993.** An approach for managing vertebrate diversity across multiple-use landscapes. Ecological Applications. 3: 481-496.

- Hardy, Colin C.; Burgan, Robert E.; Ottmar, Roger D.; Deeming, John E. 1996.** A database for spatial assessments of fire characteristics, fuel profiles, and PM10 emissions. In: Keane, Robert E.; Jones, Jeffrey L.; Riley, Laurienne S.; Hann, Wendel J., tech. eds. Compilation of administrative reports: multi-scale landscape dynamics in the basin and portions of the Klamath and Great basins. [Irregular pagination]. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Hargis, C.D. 1996.** The influence of forest fragmentation and landscape pattern on American martens and their prey. Logan, UT: Utah State University. 154 p. Ph.D. dissertation.
- Hargis, Christina D.; McCullough, Dale R. 1984.** Winter diet and habitat selection of marten in Yosemite National Park. *Journal of Wildlife Management*. 48(1): 140-146.
- Harmata, A.R. 1981.** Recoveries of ferruginous hawks banded in Colorado. *North American Bird Bander* 6:144-147.
- Harper, Kimball T.; Pendleton, Rosemary L. 1993.** Cyanobacteria and cyanolichens: can they enhance availability of essential minerals for higher plants? *Great Basin Naturalist*. 53: 59-72.
- Haynes, Richard W.; Graham, Russell T.; Quigley, Thomas M. 1998.** A framework for ecosystem management in the interior Columbia basin. *Journal of Forestry*. 96(10): 4-9.
- Hayward, G.D.; Verner, J., eds. 1994.** Flammulated, boreal, and great gray owls in the United States: a technical conservation assessment. Gen. Tech. Rep. RM-253. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 213 p.
- Helms, B. 1978.** Antelope and energy development. In: Proceedings of the 8th biennial pronghorn antelope workshop; 1978 May 2-4; Jasper, AB. Jasper, AB: Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division: 206-215.
- Hessburg, Paul F.; Smith, Bradley G.; Kreiter, Scott D. [and others]. 1999.** Historical and current forest and range landscapes in the interior Columbia River basin and portions of the Klamath and Great Basins. Part I: Linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances. Gen. Tech. Rep. PNW-GTR-458. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. (Quigley, Thomas M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Hicks, Lorin L.; Elder, James M. 1979.** Human disturbance of Sierra Nevada bighorn sheep. *Journal of Wildlife Management*. 43(4): 909-915.
- Hill, J.D.; Smith, J.D. 1984.** Bats: a natural history. Austin, TX: University of Texas Press. 243 p.
- Hodgman, T.P.; Harrison, D.J.; Katnik, D.D.; Elowe, K.D. 1994.** Survival in an intensively trapped marten population in Maine. *Journal of Wildlife Management*. 58(4): 593-600.
- Holt, Denver W. 1997.** The long-eared owl (*Asio otus*) and forest management: a review of the literature. *Journal of Raptor Research*. 32: 175-186.
- Holt, D.W. 1992.** Notes on short-eared owl (*Asio flammeus*) nest sites, reproduction and territory sizes in coastal Massachusetts. *Canadian Field-Naturalist*. 106: 352-356.

- Hornocker, M.G.; Hash, H.S. 1981.** Ecology of the wolverine in northwestern Montana. *Canadian Journal of Zoology*. 59(7): 1286-1301.
- Howard, R.P. 1975.** Breeding ecology of the ferruginous hawk in northern Utah and southern Idaho. Logan, UT: Utah State University. [Page numbers unknown]. M.A. thesis.
- Humphrey, S.R. 1975.** Nursery roosts and community diversity of nearctic bats. *Journal of Mammalogy*. 56(2): 321-346.
- Hunter, M.L., Jr. 1991.** Coping with ignorance: the coarse-filter strategy for maintaining biodiversity. In: Kohm, K.A., ed. *Balancing on the brink of extinction*. Covelo, CA: Island Press: 266-281.
- Hunter, Malcolm L. 1990.** *Wildlife, forests, and forestry: principles of managing forests*. Englewood Cliffs, NJ: Prentice-Hall. 370 p.
- Hutto, R.L. 1995.** Composition of bird communities following stand-replacement fires in northern Rocky Mountain conifer forests. *Conservation Biology*. 9(5): 1041-1058.
- Idaho State Conservation Effort. 1995.** Habitat conservation assessment and conservation strategy for the Townsend's big-eared bat. Boise, ID. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Ingles, L.G. 1965.** *Mammals of the Pacific States*. Stanford, CA: Stanford University Press. 506 p.
- Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996a.** Expert panel notes for amphibians and reptiles terrestrial habitat assessment, fall 1996, for the interior Columbia basin. Unpublished notes. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996b.** Expert panel notes for carnivore terrestrial habitat assessment, fall 1996, for the interior Columbia basin. Unpublished notes. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996c.** Expert panel notes for carnivore viability assessment, spring 1996, for the interior Columbia basin. Unpublished notes. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Interior Columbia Basin Ecosystem Management Project (ICBEMP). 1996d.** Expert panel notes for raptor and upland game bird viability assessment, spring 1996, for the interior Columbia basin. Unpublished notes. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Janes, S.W. 1983.** Status, distribution, and habitat selection of the grasshopper sparrow in Morrow County, Oregon. *Murrelet*. 64: 51-54.

- Jensen, Mark; Goodman, Iris; Brewer, Ken [and others]. 1997.** Biophysical environments of the basin. In: Quigley, Thomas M.; Arbelbide, Sylvia J., tech. eds. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins: volume 1. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 99-307. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Johansen, Jeffrey R.; Ashley, John; Rayburn, William R. 1993.** Effects of range-fire on soil algal crusts in semiarid shrub-steppe of the lower Columbia basin and their subsequent recovery. *Great Basin Naturalist*. 53: 73-88.
- Johnson, Bruce K.; Kern, John W.; Wisdom, Michael J. [and others]. 2000.** Resource selection and spatial partitioning of mule deer and elk during spring. *Journal of Wildlife Management*. 64(3): 684-697.
- Johnson, Rolf L. 1983.** Mountain goats and mountain sheep of Washington. *Biology Bulletin No. 18*. Olympia, WA: Washington State Game Department. 196 p.
- Jones, Jeffrey L. 1991.** Habitat use of fisher in north central Idaho. Moscow, ID: University of Idaho. 147 p. M.S. thesis.
- Joslin, G. 1986.** Mountain goat population changes in relation to energy exploration along Montana's Rocky Mountain front. *Biennial Symposium Northern Wild Sheep and Goat Council*. 5: 253-271.
- Kaltenecker, J.H. 1997.** The recovery of microbiotic crusts following post-fire rehabilitation on rangelands of the western Snake River plain. Boise, ID: Boise State University. 99 p. M.S. thesis.
- Kaltenecker, J.; Wicklow-Howard, M. 1994.** Microbiotic soil crusts in sagebrush habitats of southern Idaho. 48 p. (plus an appendix). Prepared for Eastside Ecosystem Management Project. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Kasworm, Wayne F.; Manley, T.L. 1990.** Road and trail influences on grizzly bears and black bears in northwest Montana. *International Conference on Bear Research and Management*. 8: 79-84.
- Keane, Robert E.; Long, Donald G.; Menakis, James P. [and others]. 1996.** Simulating coarse-scale vegetation dynamics using the Columbia River basin succession model-CRBSUM. Gen. Tech. Rep. INT-GTR-340. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 50 p.
- Keister, George P.; Immell, David. 1994.** Continued investigations of kit fox in southeastern Oregon and evaluation of status. Tech. Rep. 94-5-01. Portland, OR: Oregon Department of Fish and Wildlife, Wildlife Diversity Program. 33 p.
- Kiester, A. Ross; Scott, Michael J.; Csuti, Blair [and others]. 1996.** Conservation prioritization using GAP data. *Conservation Biology*. 10(5): 1332-1342.
- Knapton, Richard W. 1994.** Clay-colored sparrow (*Spizella pallida*). In: Poole, A.; Gill, F., eds. *The birds of North America*. No. 120. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 16 p.
- Knick, S.T.; Rotenberry, J.T. 1995.** Landscape characteristics of fragmented shrubsteppe habitats and breeding passerine birds. *Conservation Biology*. 9(5): 1059-1071.

- Knick, Steven T.; Kasworm, Wayne. 1980.** Shooting mortality in small populations of grizzly bears. *Wildlife Society Bulletin*. 17(1): 11-15.
- Knight, R.R.; Blanchard, B.M.; Eberhardt, L.L. 1988.** Mortality patterns and population sinks for Yellowstone grizzly bears, 1973-1985. *Wildlife Society Bulletin*. 16: 121-125.
- Koehler, G.M.; Brittell, J.D. 1990.** Managing spruce fir habitat for lynx and snowshoe hares. *Journal of Forestry*. 88: 10-14.
- Koehler, Gary M.; Hornocker, Maurice G. 1977.** Fire effects on marten habitat in the Selway-Bitterroot Wilderness. *Journal of Wildlife Management*. 41(3): 500-505.
- Koehler, Gary M.; Aubry, Keith B. 1994.** Lynx. In: Ruggiero, L.; Aubry, K.; Buskirk, S. [and others], tech. eds. 1994. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the Western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 74-98. Chapter 4.
- Koplin, James R. 1969.** The numerical response of woodpeckers to insect prey in a subalpine forest in Colorado. *Condor*. 71(4): 436-438.
- Krebs, Charles J. 1989.** Ecological methodology. New York: Harper-Collins. 654 p.
- Landres, Peter B.; Verner, Jared; Thomas, Jack Ward. 1988.** Ecological uses of vertebrate indicator species: a critique. *Conservation Biology*. 2(4): 316-328.
- Lanyon, W.E. 1994.** Western meadowlark (*Sturnella neglecta*). In: Poole, A.; Gill, F., eds. The birds of North America. No. 104. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 20 p.
- Lee, Danny C.; Sedell, James R.; Rieman, Bruce E. [and others]. 1997.** Broad-scale assessment of aquatic species and habitats. In: Quigley, Thomas M.; Arbelbide, Sylvia J., tech. eds. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1057-1496. Vol. 3. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Lee, Danny C.; Sedell, James R.; Rieman, Bruce E. [and others]. 1998.** Aquatic species and habitats. *Journal of Forestry*. 96(10): 16-21.
- Lehmkuhl, John F.; Raphael, Martin G.; Holthausen, Richard S. [and others]. 1997.** Historical and current status of terrestrial species and the effects of proposed alternatives. In: Quigley, Thomas M.; Lee, Kristine M.; Arbelbide, Sylvia J., tech. eds. Evaluation of EIS alternatives by the Science Integration Team. Gen. Tech. Rep. PNW-GTR-406. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 537-730. Vol. 2.
- Lewis, Lyle; Wenger, C. Richard. 1998.** Idaho's Canada lynx: pieces of the puzzle. Tech. Bull. 98-11. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office. 19 p.
- Linden, H.; Wikman, M. 1983.** Goshawk predation on tetraonids: availability of prey and diet of the predator in the breeding season. *Journal of Animal Ecology*. 52: 953-968.

- Lokemoen, J.T.; Duebbert, H.F. 1976.** Ferruginous hawk nesting ecology and raptor populations in northern South Dakota. *Condor*. 78(4): 464-470.
- Losensky, B. John. 1995.** A description and photographic record of the historical vegetation of the Columbia River basin. Walla Walla, WA: Interior Columbia Basin Ecosystem Management Project; completion report; contract INT-94951-RJVA. [Irregular pagination]. On file with: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Science Laboratory, 800 Block E. Beckwith, P.O. Box 8089, Missoula, MT 59807.
- Losensky, B. John. 1994.** Historical vegetation types of the interior Columbia River basin. Walla Walla, WA: Interior Columbia Basin Ecosystem Management Project; completion report; contract INT-94951-RJVA. [Irregular pagination]. On file with: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Forestry Science Laboratory, 800 Block E. Beckwith, P.O. Box 8089, Missoula, MT 59807.
- Loveland, T.R.; Merchant, J.M.; Ohlen, D.O.; Brown, J.F. 1991.** Development of a land-cover characteristics database for the conterminous U.S. *Photogrammetric Engineering and Remote Sensing*. 57(11): 1453-1463.
- Luckenbach, Roger A. 1978.** An analysis of off-road vehicle use on desert avifaunas. *Transactions of the North American Wildlife and Natural Resources Conference*. 43: 157-162.
- Ludwig, John A.; Reynolds, James F. 1988.** *Statistical ecology*. New York: John Wiley and Sons. 337 p.
- Lyon, L. Jack. 1983.** Road density models describing habitat effectiveness for elk. *Journal of Forestry* 81: 592-595.
- MacArthur, R.A.; Geist, V.; Johnston, R.H. 1982.** Cardiac and behavioral responses of mountain sheep to human disturbance. *Journal of Wildlife Management*. 46: 351-358.
- MacArthur, R.A.; Johnston, R.H.; Geist, V. 1979.** Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. *Canadian Journal of Zoology*. 57: 2010-2021.
- MacCracken, J.G.; Alexander, L.E.; Uresk, D.W. 1983.** An important lichen of southeastern Montana rangelands. *Journal of Range Management*. 36: 35-37.
- Mace, Richard D.; Waller, John S.; Manley, Timothy L. [and others]. 1996.** Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. *Journal of Applied Ecology*. 33: 1395-1404.
- Mack, R.N.; Thompson, J.N. 1982.** Evolution in steppe with few large, hooved mammals. *American Naturalist*. 119: 757-773.
- Mader, H.J. 1984.** Animal habitat isolation by roads and agricultural fields. *Biological Conservation*. 29: 81-96.
- Magoun, Audrey J.; Copeland, Jeffrey P. 1998.** Characteristics of wolverine reproductive den sites. *Journal of Wildlife Management*. 62: 1313-1320.
- Maj, M.; Garton, E.O. 1994.** Fisher, lynx, and wolverine summary of distribution information. In: Ruggiero, L.; Aubry, K.; Buskirk, S. [and others], tech eds. 1994. *The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the Western United States*. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 169-175. (appendix B).

- Mannan, R.W.; Morrison, Michael L.; Meslow, E. Charles. 1984.** Comment: the use of guilds in forest bird management. *Wildlife Society Bulletin*. 12: 426-430.
- Manning, R.W.; Knox-Jones, J. 1989.** *Myotis evotis*. *Mammalian Species*. No. 329. Baltimore, MD: American Society of Mammalogists. 5 p.
- Marcot, Bruce G.; Castellano, Michael A.; Christy, John A. [and others]. 1997.** Terrestrial ecology of the basin. In: Quigley, Thomas M.; Arbelbide, S.J., tech. eds. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1497-1713. Vol. 3. (Quigley, Thomas M., tech. ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Marcot, Bruce G.; Wales, Barbara C.; Murphy, Wally. [In prep.].** Range maps for terrestrial vertebrates in the interior Columbia basin. On file with: Bruce Marcot, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 1221 S.W. Yamhill Street, Suite 200, Portland, OR 97208.
- Marcot, Bruce G.; Wisdom, Michael J.; Li, Hiram W.; Castillo, Gonzalo C. 1994.** Managing for featured, threatened, endangered, and sensitive species and unique habitats for ecosystem sustainability. Gen. Tech. Rep. PNW-GTR-329. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 39 p.
- Marks, J.S.; Saab Marks, V. 1987.** Influence of radio collars on survival of sharp-tailed grouse. *Journal of Wildlife Management*. 51(2): 468-471.
- Marti, C.D.; Marks, J.S. 1989.** Medium-sized owls. Proceedings of the western raptor management symposium and workshop; 1987 October 26-28; Boise, ID. National Wildlife Federation Science and Technical Series. 12: 124-133.
- Martin, Kevin D.; Schommer, Tim; Coggins, Victor. 1996.** Literature review regarding the compatibility between bighorn and domestic sheep. Biennial Symposium of the Northern Wild Sheep and Goat Council. 10: 72-77.
- Maser, C.; Hammer, E.W.; Brown, C. [and others]. 1974.** The sage vole, *Lagurus curtatus*, in the Crooked River National Grassland, Jefferson County, Oregon: a contribution to its life history and ecology. *Saegetierkundliche Mitteilungen*. 22: 193-222.
- Maser, C.; Strickland, G.S. 1978.** The sage vole, *Lagurus curtatus*, as an inhabitant of subalpine sheep fescue *Festuca ovina* communities on Steens Mountain: an observation and interpretation. *Northwest Science*. 52: 276-284.
- Matthews, Patrick E.; Coggins, Victor L. 1994.** Status and history of mountain goats in Oregon. Biennial Symposium of the Northern Wild Sheep and Goat Council. 9: 69-74.
- Mattson, David J.; Blanchard, Bonnie M.; Knight, Richard R. 1992.** Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. *Journal of Wildlife Management*. 56(3): 432-442.
- Mattson, David J.; Herrero, Stephen; Wright, Gerald; Pease, Craig M. 1996a.** Designing and managing protected areas for grizzly bears: how much is enough? In: Wright, R.G., ed. National parks and protected areas: their role in environmental protection. Cambridge, MA: Blackwell Science: 133-164.

- Mattson, David J.; Herrero, Stephen; Wright, Gerald; Pease, Craig M. 1996b.** Science and management of Rocky Mountain grizzly bears. *Conservation Biology*. 10(4): 1013-1025.
- Mattson, David J.; Knight, Richard R.; Blanchard, Bonnie M. 1987.** The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. *International Conference on Bear Research and Management*. 7: 259-273.
- Mattson, D.J.; Wright, G.R.; Kendall, K.C.; Martinka, C.J. 1995.** Grizzly bears. In: LaRoe, E.T.; Farris, G.S.; Puckett, C.E. [and others], eds. *Our living resources*. Washington, DC: U.S. Department of the Interior, National Biological Service: 103-105.
- McKelvey, Kevin S.; Aubry, Keith B.; Ortega, Yvette K. 1999.** History and distribution of lynx in the contiguous United States. In: Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W. [and others], eds. *Ecology and conservation of lynx in the United States*. Niwot, CO: University Press of Colorado, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 207-264. Chapter 8.
- McLellan, B.N.; Shackleton, D.M. 1988.** Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use, and demography. *Journal of Applied Ecology*. 25: 451-460.
- Mech, L.D. 1970.** Implications of wolf ecology to management. In: Jorgensen, S.E.; Faulkner, L.E.; Mech, L.D., eds. *Proceedings of a symposium on wolf management in selected areas of North America*. [Meeting dates unknown]; [Meeting location unknown]. [Place of publication unknown]: U.S. Department of the Interior, Fish and Wildlife Service: 39-44.
- Mech, L.D. 1973.** Wolf numbers in the Superior National Forest of Minnesota. Res. Pap. NC-97. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Experiment Station. 10 p.
- Mech, L.D. 1980.** Age, sex, reproduction, and spatial organization of lynxes colonizing northeastern Minnesota. *Journal of Mammology*. 61: 261-267.
- Mech, L.D.; Fritts, S.H.; Radde, G.L.; Paul, W.J. 1988.** Wolf distribution and road density in Minnesota. *Wildlife Society Bulletin*. 16: 85-87.
- Meints, D.R.; Connelly, J.W.; Reese, K.P. [and others]. 1992.** Habitat suitability index procedure for Columbian sharp-tailed grouse. Idaho Forest Wildlife and Range Experiment Station Bulletin. Moscow, ID: University of Idaho, College of Forestry and Range Sciences. (vi): 1-27.
- Menakis, James P.; Long, Donald G.; Keane, Robert E. 1996.** The development of key broad-scale layers and characterization files. In: Keane, Robert E.; Jones, Jeffrey L.; Riley, Laurienne S.; Hann, Wendel J., tech. eds. *Compilation of administrative reports: multi-scale landscape dynamics in the basin and portions of the Klamath and Great basins*. [Irregular pagination]. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Merriam, G.; Kozakiewicz, M.; Tsuchiya, E.; Hawley, K. 1988.** Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. *Landscape Ecology*. 2: 227-235.
- Merrill, Troy; Mattson, David J.; Wright, R. Gerald; Quigley, Howard B. 1999.** Defining landscapes suitable for restoration of grizzly bears *Ursus arctos* in Idaho. *Biological Conservation*. 87(2): 231-248.
- Miller, J.R.; Joyce, L.A.; Knight, R.L.; King, R.M. 1996.** Forest roads and landscape structure in the southern Rocky Mountains. *Landscape Ecology*. 11: 115-127.

- Mladenoff, David J.; Sickley, Theodore A.; Haight, Robert G.; Wydeven, Adrian P. 1995.** A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. *Conservation Biology*. 9(2): 279-294.
- Moroz, Paul. 1995.** Idaho ground squirrel, *Spermophilus brunneus brunneus*, habitat conservation assessment (HCA), conservation strategy (CS). Idaho Interagency Conservation/Prelisting Effort. Idaho Department of Fish and Game; Idaho Department of Parks and Recreation; U.S. Department of the Interior, Fish and Wildlife Service and Bureau of Land Management; U.S. Department of Agriculture, Forest Service. 26 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Morrison, M.L.; Marcot, B.G.; Mannan, R.W. 1992.** Wildlife-habitat relationships: concepts and applications. Madison, WI: University of Wisconsin Press. 343 p.
- Murray, T.B. 1938.** Upland game birds in Idaho and their future. *University of Idaho Bulletin* 33: 55-60.
- Nagorsen, D.W.; Brigham, R.M. 1993.** Bats of British Columbia. Vancouver, BC: UBC Press. 164 p.
- Nellis, Carl H.; Wetmore, Stephen P.; Keith, Lloyd B. 1972.** Lynx-prey interactions in central Alberta. *Journal of Wildlife Management*. 36(2): 320-329.
- Noss, R.F. 1987.** From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). *Biological Conservation*. 41: 11-37.
- Noss, R.F.; LaRoe, E.T., III; Scott, J.M. 1995.** Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biological report 28. Washington, DC: National Biological Service.
- Noss, Reed F.; Quigley, Howard B.; Hornocker, Maurice G. [and others]. 1996.** Conservation biology and carnivore conservation in the Rocky Mountains. *Conservation Biology*. 10(4): 949-963.
- Nussbaum, Ronald A.; Brodie, Edmund D., Jr.; Storm, Robert M. 1983.** Amphibians and reptiles of the Pacific Northwest. Moscow, ID: University of Idaho Press. 332 p.
- Oakley, C.; Riddle, P. 1974.** The impact of a severe winter and fences on antelope mortality in south central Wyoming. Proceedings of the 6th antelope states workshop; 1974 February 19 -21; Salt Lake City, UT. [Place of publication unknown]: [Publisher unknown]: 155-171.
- Olendorff, R.R.; Stoddart, J.W., Jr. 1974.** The potential for management of raptor populations in western grassland. In: Hamerstrom, F.N.; Harrell, B.N.; Olendorff, R.R., eds. Management of raptors: Proceedings of the conference on raptor conservation, part 4; 1973 March 22-24; Fort Collins, CO. Vermillion, SD: Raptor Research Foundation. Raptor Research Reports. 2: 44-48.
- Onderka, D.K.; Wishart, W.D. 1984.** A major die-off from pneumonia in southern Alberta. Proceedings of the biennial symposium of the Northern Wild Sheep and Goat Council. Helena, MT: Idaho Department of Fish and Game. 4: 356-363.
- Orloff, S.; Hall, E.; Spiegel, L. 1986.** Distribution and habitat requirements of the San Joaquin kit fox in the northern extreme of their range. *Transactions of the Western Section of the Wildlife Society*: 2260-2270.
- Ormsbee, Patricia C.; McComb, William C. 1998.** Selection of day roosts by female long-legged myotis in the central Oregon Cascade Range. *Journal of Wildlife Management*. 62(2): 596-602.

- Ottmar, Roger D.; Alvarado, Ernesto; Hessburg, Paul F. [and others]. 1996.** Historical and current forest and range landscapes in the interior Columbia River basin and portions of the Klamath and Great basins. Part II: Linking vegetation patterns to potential smoke production and fire behavior. Draft report. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Oxley, D.J.; Fenton, M.B. 1974.** The effects of roads on populations of small mammals. *Journal of Applied Ecology*. 25: 1073-1087.
- Paragi, T.F.; Arthur, S.M.; Krohn, W.B. 1994.** Seasonal and circadian activity patterns of female fishers, *Martes pennanti*, with kits. *Canadian Field Naturalist*. 108(1): 52-57.
- Parker, G.R.; Maxwell, J.W.; Morton, L.D. [and others]. 1983.** The ecology of lynx (*Lynx canadensis*) on Cape Breton Island. *Canadian Journal of Zoology*. 61: 770-786.
- Perkins, J. Mark; Peterson, Joshua R. 1997.** Bat distribution in the juniper woodlands of the Idaho Owyhee Mountains, summer 1996. Tech. Bull. 97-4. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office. 12 p.
- Perlmeter, S.I. 1995.** Bats and bridges: a field study of the thermal conditions and social organization of night roosts in the Willamette National Forest. North York, ON: York University. 98 p. M.S. thesis.
- Pierson, Elizabeth D.; Rainey, William E.; Koontz, Dolora M. 1991.** Bats and mines: experimental mitigation for Townsend's big-eared bat at the McLaughlin mine in California. In: Corner, R.D., Davis, P.R., Foster, S.Q. [and others], eds. *Proceedings V: issues and technology in the management of impacted wildlife; 1991 April 8-10; Snowmass Resort, CO*. Boulder, CO: Thorne Ecological Institute: 31-42.
- Pletscher, Daniel H.; Ream, Robert R.; Boyd, Diane K. [and others]. 1997.** Population dynamics of a recolonizing wolf population. *Journal of Wildlife Management*. 61(2): 459-465.
- Poulton, C.E. 1955.** Ecology of the non-forested vegetation in Umatilla and Morrow Counties, Oregon. Pullman, WA: Washington State University. 166 p. Ph.D. dissertation.
- Pulliam, H.R. 1988.** Sources, sinks, and population regulation. *American Naturalist*. 132(5): 652-661.
- Pulliam, H.R.; Danielson, B.J. 1991.** Sources, sinks, and habitat selection: a landscape perspective on population dynamics. *American Naturalist*. 137: 55-66.
- Quick, H.F. 1956.** Effects of exploitation on a marten population. *Journal of Wildlife Management*. 20(3): 267-274.
- Quigley, Thomas M.; Haynes, Richard W.; Graham, Russell T., tech. eds. 1996.** Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p. (Quigley, Thomas M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Rabe, Michael J.; Morrell, Thomas E.; Green, Heather [and others]. 1998.** Characteristics of ponderosa pine snag roosts used by reproductive bats in northern Arizona. *Journal of Wildlife Management*. 62(2): 612-621.
- Ramakka, J.M.; Woyewodzic, R.T. 1993.** Nesting ecology of ferruginous hawk in northwestern New Mexico. *Journal of Raptor Research*. 27(2): 97-101.

- Raphael, Martin G.; Marcot, Bruce G.; Holthausen, Richard S.; Wisdom, Michael J. 1998.** Terrestrial species and habitats. *Journal of Forestry*. 96(10): 22-27.
- Reed, Rebecca A.; Johnson-Barnard, Julia; Baker, William L. 1996.** Contribution of roads to forest fragmentation in the Rocky Mountains. *Conservation Biology*. 10: 1098-1106.
- Reynolds, R.T.; Graham, R.T.; Reiser, M.H. [and others]. 1992.** Management recommendations for the northern goshawk in the Southwestern United States. Gen. Tech. Rep. RM-217. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184 p.
- Rich, T.D.; Rothstein, S.I. 1985.** Sage thrashers reject cowbird eggs. *Condor*. 87: 561-562.
- Rickard, William H.; Poole, Linda D. 1989.** Terrestrial wildlife of the Hanford Site: past and future. *Northwest Science*. 63(4): 183-192.
- Romesburg, H.C. 1984.** Cluster analysis for researchers. Belmont, CA: Lifetime Learning Publications. 334 p.
- Rowland, Mary M.; Wisdom, Michael J.; Johnson, Bruce K. [and others]. 2000.** Elk distribution and modeling in relation to roads. *Journal of Wildlife Management*. 64(3): 672-684.
- Rudolph, Karen M.; Cowan, Lisa M.; Hunter, David L. [and others]. [In prep.].** Sharing of *Pasteurella* spp. among free-ranging bighorn sheep, domestic sheep, and feral goats.
- Ruediger, Bill. 1996.** The relationship between rare carnivores and highways. In: Evink, G.; Garrett, P.; Berry, J., eds. Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. Proceedings of a symposium; 1996 April 3-May 2; Orlando, FL. Orlando, FL: Department of Transportation, Federal Highway Administration: 24-38.
- Ruggiero, Leonard F.; Aubry, Keith B.; Buskirk, Steven W. [and others]. 1999.** Ecology and conservation of lynx in the United States. Niwot, CO: University Press of Colorado and U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 480 p.
- Ryan, L.A.; Carey, A.B. 1995.** Biology and management of the western gray squirrel and Oregon white oak woodlands: with emphasis on the Puget Trough. Gen. Tech. Rep. PNW-GTR-348. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 36 p.
- Saab, V.A.; Bock, C.E.; Rich, T.D.; Dobkin, D.S. 1995.** Livestock grazing effects in western North America. In: Martin, Thomas E.; Finch, Deborah M., eds. Ecology and management of neotropical migratory birds. New York: Oxford University Press: 311-353.
- Saab, V.A.; Marks, J.S. 1992.** Summer habitat use by Columbian sharp-tailed grouse in western Idaho. *Great Basin Naturalist*. 52(2): 166-173.
- Saab, V.A.; Rich, T.D. 1997.** Large-scale conservation assessment for neotropical migratory land birds in the interior Columbia River basin. Gen. Tech. Rep. PNW-GTR-399. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 57 p. (Quigley, Thomas M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Sarell, M.J.; McGuinness, K.P. 1993.** Rare bats of the shrub-steppe ecosystem of eastern Washington. Gen. Tech. Rep. Olympia, WA: Washington Department of Wildlife.

- SAS Institute, Inc. 1989a.** Cluster procedure. In: SAS/STAT user's guide, version 6. 4th ed. SAS Institute: 519-614. Vol. 1. Available from: SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513.
- SAS Institute, Inc. 1989b.** Corr procedure. SAS procedures guide, version 6. 3d ed. SAS Institute: 209-235. Available from: SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513.
- SAS Institute, Inc. 1989c.** Tree procedure. SAS/STAT user's guide, version 6. 4th ed. SAS Institute: 1613-1632. Vol. 2. Available from: SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513.
- Sauer, J.R.; Peterjohn, B.J.; Schwartz, S.; Hines, J.E. 1996a.** The North American breeding bird survey home page; version 95.1. Laurel, MD: Patuxent Wildlife Research Center. URL <http://www.mbr-pwrc.usgs.gov/bbs/bbsold.html>.
- Sauer, John R.; Pendleton, Grey W.; Peterjohn, Bruce G. 1996b.** Evaluating causes of population change in North American insectivorous songbirds. *Conservation Biology*. 10(2): 465-478.
- Schmutz, J.K. 1984.** Ferruginous and Swainson's hawk abundance and distribution in relation to land use in southeastern Alberta. *Journal of Wildlife Management*. 48(4): 1180-1187.
- Schuler, Carol A.; Rickard, William H.; Sargeant, Glen A. 1993.** Conservation of habitats for shrub-steppe birds. *Environmental Conservation*. 20(1): 57-64.
- Scott, M.D.; Servheen, G. 1985.** Caribou ecology. Boise, ID: Idaho Department of Fish and Game; job comp. report, proj. no. W-160-R-11. 136 p.
- Scott, Michael J.; Davis, Frank; Csuti, Blair [and others]. 1993.** GAP analysis: a geographic approach to protection of biological diversity. *Wildlife Monograph* no. 123. 41 p.
- Singer, F.J. 1978.** Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. *Journal of Wildlife Management*. 42(3): 591-597.
- Smith, Michael Roger. 1994.** Evaluating the conservation of avian diversity in eastern Washington: a geographic analysis of upland breeding birds. Seattle: University of Washington. 89 p. M.S. thesis.
- Smith, R.L. 1963.** Some ecological notes on the grasshopper sparrow. *Wilson Bulletin*. 75(2): 159-165.
- Southern Appalachian Man and the Biosphere Cooperative (SAMAB). 1996.** The Southern Appalachian assessment summary report. Rep. 1. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 118 p.
- Spraker, T.R.; Hibbler, C.P.; Schoonveld, G.G.; Adbetm, W.S. 1984.** Pathological changes and microorganisms found during a stress related die-off. *Journal of Wildlife Diseases*. 20: 319-327.
- Squires, J.R.; Reynolds, R.T. 1997.** Northern goshawk (*Accipiter gentilis*). In: Poole, A.; Gill, F., eds. *The birds of North America*. No. 298. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 32 p.
- St. Clair, L.L.; Johansen, J.R. 1993.** Introduction to the symposium on soil crust communities. *Great Basin Naturalist*. 53(1): 1-4.
- St. Clair, Larry L.; Johansen, Jeffrey R.; Rushforth, Samuel R. 1993.** Lichens of soil crust communities in the Intermountain area of the Western United States. *Great Basin Naturalist*. 53: 5-12.

- Stebbins, Robert C. 1985.** Peterson field guides: western reptiles and amphibians. Boston, MA: Houghton Mifflin Co. 336 p.
- Stelfox, John G. 1971.** Bighorn sheep in the Canadian Rockies: a history 1800-1970. The Canadian Field-Naturalist. 85: 101-122.
- Swihart, R.K.; Slade, N.A. 1984.** Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. Journal of Mammalogy. 65: 357-360.
- Szaro, Robert C. 1986.** Guild management: an evaluation of avian guilds as a predictive tool. Environmental Management. 10(5): 681-688.
- Taylor, Elroy; McCoy, Matthew; Bodie, Walt. 1993.** California bighorn sheep ecology. Study II: habitat selection. Jobs 1 and 3. Boise, ID: Idaho Department of Fish and Game; job completion rep.; proj. no. W-160-R-20. 34 p.
- Terra-Berns, Mary; Call, Paula; Harris, Chuck [and others]. 1997.** Canada lynx in Idaho: past, present, and future. Boise, ID: Idaho Department of Fish and Game. 79 p.
- Thiel, R.P. 1985.** Relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist. 113: 404-407.
- Thomas, Jack Ward; Anderson, Ralph G.; Maser, Chris; Bull, Evelyn L. 1979.** Snags. In: Thomas, Jack Ward, tech. ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Agric. Handb. No. 553. Washington, DC: U.S. Department of Agriculture: 60-77.
- Thompson, I.D. 1994.** Marten populations in uncut and logged boreal forests in Ontario. Journal of Wildlife Management. 58(2): 272-280.
- Thompson, I.D.; Colgan, P.W. 1987.** Numerical responses of martens to a food shortage in north central Ontario. Journal of Wildlife Management. 51(4): 824-835.
- Thurber, Joanne M.; Peterson, Rolf O.; Drummer, Thomas D.; Thomasma, Scott A. 1994.** Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin. 22(1): 61-68.
- Tirhi, M.J. 1995.** Washington state management plan for sharp-tailed grouse. Olympia, WA: Washington Department of Fish and Wildlife, Wildlife Management Program. 99 p.
- Tobalske, B.W. 1997.** Lewis' woodpecker (*Melanerpes lewis*). In: Poole, A.; Gill, F., eds. The birds of North America. No. 284: Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 28 p.
- Tomich, P. Quentin. 1982.** Ground squirrels (*Spermophilus beecheyi* and allies). In: Chapman, Joseph A.; Feldhamer, George A., eds. Wild mammals of North America: biology, management, and economics. Baltimore, MD: Johns Hopkins University Press: 192-208.
- Trombulak, S.C.; Frissell, C.A. 2000.** Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14: 18-30.
- Tuttle, M.D. 1988.** America's neighborhood bats. Austin, TX: University of Texas Press. 96 p.
- Unsworth, J.M.; Kuck, L.; Scott, M.D.; Garton, E.O. 1993.** Elk mortality in the Clearwater Drainage of northcentral Idaho. Journal of Wildlife Management. 57: 495-502.

- U.S. Department of Agriculture, Forest Service. 1996.** Status of the interior Columbia basin: summary of scientific findings. Gen. Tech. Rep. PNW-GTR-385. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; U.S. Department of the Interior, Bureau of Land Management. 144 p.
- U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994.** Record of decision for amendments to Forest Service and Bureau of Land Management planning document within the range of the northern spotted owl. [Place of publication unknown]. 74 p. [plus Attachment A: standards and guidelines].
- U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1997a.** Eastside draft environmental impact statement. Boise, ID: Interior Columbia Basin Ecosystem Management Project. [Irregular pagination]. 2 vol.
- U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1997b.** Upper Columbia River basin draft environmental impact statement. Boise, ID: Interior Columbia Basin Ecosystem Management Project. [Irregular pagination]. 2 vol.
- U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Fish and Wildlife Service. 1996.** Conservation agreement: *Spermophilus brunneus brunneus*, northern Idaho ground squirrel. McCall, ID: U.S. Department of Agriculture, Forest Service, Payette National Forest; Boise, ID: U.S. Department of the Interior, Fish and Wildlife Service. 14 p.
- U.S. Department of the Interior, Bureau of Land Management. 1997.** Proposed standards for rangeland health and guidelines for livestock grazing management. BLM/ID/PT-97/002+4120. Boise ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office.
- U.S. Department of the Interior, Fish and Wildlife Service. 1987.** Northern Rocky Mountain wolf recovery plan. Denver, CO: U.S. Department of the Interior, Fish and Wildlife Service. 119 p.
- Van Ballenberghe, Victor; Erickson, Albert W.; Byman, David. 1975.** Ecology of the timber wolf in north-eastern Minnesota. Wildlife Monographs. No. 43. 43 p.
- Verner, Jared. 1984.** The guild concept applied to management of bird populations. Environmental Management. 8(1): 1-14.
- Vestjens, W.J.M. 1973.** Wildlife mortality on a road in New South Wales. Emu. 73: 107-112.
- Vogel, C.A.; Reese, K.P. 1995.** Mountain quail status report: a document preliminary to a habitat conservation assessment for mountain quail. 33 p. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 304 N. 8th Street, Boise, ID 83702.
- Wai-Ping, V.; Fenton, M.B. 1989.** Ecology of the spotted bat (*Euderma maculatum*) roosting and foraging behavior. Journal of Mammalogy. 70(3): 617-622.
- Wakelyn, Leslie A. 1987.** Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management. 51(4): 904-912.
- Ward, J.M.; Kennedy, P.L. 1996.** Effects of supplemental food on size and survival of juvenile northern goshawks. Auk. 113: 200-208.

- Ward, Richard M.P.; Krebs, Charles J. 1985.** Behavioural responses of lynx to declining snowshoe hare abundance. *Canadian Journal of Zoology*. 63(12): 2817-2824.
- Western, David; Pearl, Mary C., eds. 1989.** Conservation for the twenty-first century. New York: Oxford University Press. 365 p.
- Whitaker, John O., Jr.; Maser, Chris; Keller, Laurel E. 1977.** Food habits of bats of western Oregon. *Northwest Science*. 51(1): 46-55.
- White, C.E. 1974.** Current problems and techniques in raptor management and conservation. *Transactions of the North American Wildlife Conference*. 39: 301-312.
- White, C.M.; Thurow, T.L. 1985.** Reproduction of ferruginous hawks exposed to controlled disturbance. *Condor*. 87(1): 14-22.
- Wielgus, Robert B.; Bunnell, Fred, L. 1995.** Tests of hypotheses for sexual segregation in grizzly bears. *Journal of Wildlife Management*. 59(3): 552-560.
- Wiens, John A.; Rotenberry, John T. 1981.** Habitat associations and community structure of birds in shrub-steppe environments. *Ecological Monographs*. 5(1): 21-41.
- Wisdom, Michael J.; Cimon, Norman J.; Johnson, Bruce K. [and others]. 1999.** Distribution and spatial partitioning of mule deer and elk in relation to traffic. Unpublished report. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1401 Gekeler Lane, La Grande, OR 97850.
- Wisdom, Michael J. 2000.** Overlays and correspondence of lynx and wolverine occurrence data with habitat abundance and road density estimates in the Interior Columbia Basin. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.
- Wishart, William. 1978.** Bighorn sheep. In: Schmidt, John L.; Gilbert, Douglas L., eds. *Big game of North America: ecology and management*. Harrisburg, PA: Stackpole Books: 161-171.
- Witmer, Gary W.; Martin, Sandra K.; Sayler, Rodney D. 1998.** Forest carnivore conservation and management in the interior Columbia basin: issues and environmental correlates. Gen. Tech. Rep. PNW-GTR-420. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 51 p. (Quigley, Thomas M., ed.; Interior Columbia Basin Ecosystem Management Project: scientific assessment).
- Yoakum, J. 1980.** Habitat management guides for the American pronghorn antelope. Tech. Note 347. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 77 p.
- Yoakum, James D. 1978.** Pronghorn. In: Schmidt, John L.; Gilbert, Douglas L., eds. *Big game of North America*. Harrisburg, PA: Stackpole Books: 103-121.
- Yosef, R. 1996.** Loggerhead shrike (*Lanius ludovicianus*). In: Poole, A.; Gill, F., eds. *The birds of North America*. No. 231. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 28 p.
- Zwicker, Fred C. 1992.** Blue grouse, *Dendragapus obscurus*. In: Poole, Alan F.; Stettenheim, Peter; Gill, Frank B., eds. *The birds of North America*. No. 15. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union. 28 p.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208-3890

